AD-A080 945 ARINC RESEARCH CORP ANNAPOLIS MD F/G 17/7
AVIONICS COST DEVELOPMENT FOR CIVIL APPLICATION OF GLOBAL POSIT--ETC(U)
APR 79 S H KOWALSKI DOT-FA76WA-3788
UNCLASSIFIED 1326-01-7-1873 FAA-EM-79-1 NL

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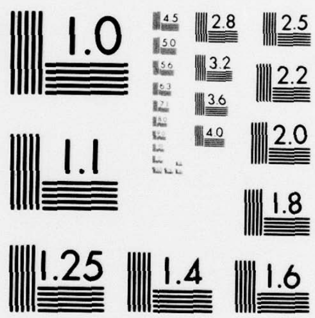

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DTIC ACCESSION NUMBER

II

LEVEL

INVENTORY

ARINC Research Corp. Publication 1326-01-7-1873
FAA Rpt. No. EM-79-1

DOCUMENT IDENTIFICATION

Dtd. April 1979

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Report No. FAA-EM-79-1

Publication 1326-01-7-1873

AVIONICS COST DEVELOPMENT FOR CIVIL APPLICATION OF GLOBAL POSITIONING SYSTEM

FINAL REPORT

S. Kowalski

April 1979

PREPARED FOR

U.S. DEPARTMENT OF TRANSPORTATION

FEDERAL AVIATION ADMINISTRATION

Office of Systems Engineering Management
Washington, D.C. 20591

Technical Report Documentation Page

1. Report No. FAA-EM-79-1	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Avionics Cost Development for Civil Application of Global Positioning System		5. Report Date April 1979
		6. Performing Organization Code
7. Author(s) S. H. Kowalski		8. Performing Organization Report No. 1326-01-7-1873
9. Performing Organization Name and Address ARINC Research Corporation a Subsidiary of Aeronautical Radio, Inc. 2551 Riva Road Annapolis, Maryland 21401		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. DOT-FA76WA-3788
		13. Type of Report and Period Covered Final Report
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Office of Systems Engineering Management Washington, D.C. 20591		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

This report presents the results of the cost analysis of avionics required in support of the civil application of the Global Positioning System (GPS). The design considered for analysis was chosen because of the advanced state of development which provided the necessary data for cost evaluations.

The costs of avionics were developed using both the parametric and accounting methods of cost estimating.

17. Key Words GPS	18. Distribution Statement Document is available to the Public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages ~~96~~ 110	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

ACKNOWLEDGEMENT

Throughout this study to develop avionics costs for civil application of the Global Positioning System, ARINC Research Corporation received enthusiastic and invaluable support from the management and engineering departments of the USAF Space and Missile Systems Organization and the Advanced Products Division of the Magnavox Corporation. The Federal Aviation Administration provided the overall guidance for the study, while the other organizations supplied necessary technical and economic data.

SUMMARY

The avionics cost development for civil use of the Global Positioning System (GPS), performed for the Federal Aviation Administration (FAA) Office of Systems Engineering Management (OSEM), was based on two accepted cost-estimating methods: parametric and accounting. The parametric method was employed to obtain early indication of the probable cost of the GPS civil avionics. The more detailed accounting method, which is based on actual production bills of materials, was exercised to refine the parametrically predicted cost of avionics that duplicate the performance of the system evaluated.

The system evaluated is the military-developed "Z" set modified to meet the packaging requirements of air carrier and general-aviation avionics. Consideration of the "Z" set was mandated by the advanced state of development of this design and the availability of data necessary for cost evaluation. The signal format, signal acquisition, and frequency-conversion techniques, as well as data processing and display, are identical to those in the military "Z" set, assuring that the system's performance will be the same as that provided by the "Z" set. Instead of evaluating the applicability of the "Z" set performance to civil navigation requirements, the study merely developed the cost of avionics for a civil system with comparable performance.

The civil GPS system requires a receiver, control and display unit, antenna, and preamplifier. High-performance aircraft would probably have at least one set of each installed in conventional locations within the airframe. In many cases a second, fully redundant system would be provided. Low-performance aircraft would probably use a combined antenna-preamplifier package, with the receiver remotely mounted and the control in the console of the aircraft. The expected cost of these equipments for the high-performance aircraft is presented in Table S-1. The results are presented in 1977 dollars, with no escalation during the manufacturing period. The 1977 dollar was used to maintain consistency with the cost and design data contained in the critical design review of the "Z" set conducted in December 1977. Separate data have been presented for air carrier and general-aviation users to account for large-volume procurement of fleet owners buying from the manufacturers and the limited-quantity purchase of the private aircraft owner, who is expected to subsidize distribution costs. In addition, separate data have been presented for the two methods of cost estimating to allow comparison of results. The parametric method estimates both the development and production costs, which together constitute the

Table S-1. ACQUISITION COST OF HIGH-PERFORMANCE AIRCRAFT GPS AVIONICS						
Equipment	Cost (Dollars) by User Category					
	Parametric Method				Accounting Method	
	Development Only	Production Only	Air Carrier*	General* Aviation	Air Carrier	General Aviation
Receiver	681	9,131	9,812	12,756	8,811	11,454
Control and Display	92	1,208	1,300	1,690	1,223	1,589
Preamplifier	56	671	727	945	708	920
Antenna	25	205	230	299	230	299
Total Cost	854	11,215	12,069	15,690	10,972	14,262

*Includes development costs.

factory selling price of the system (shown as the cost to air carriers). The accounting method of estimating the cost of high-performance aircraft avionics, however, considers only the production costs. Comparison of results developed by the two methods used must be based on the production data. This comparison shows that the two methods of cost estimating produce results on the cost of GPS civil avionics that are within two percent.

Table S-2 presents the results of the evaluation for low-performance aircraft GPS avionics. Both methods of cost estimating can be considered as including development costs and are directly comparable. The results are within 12 percent, with the accounting method showing the higher expected costs. This variation has been examined and attributed to the unequal sensitivity of the cost-estimating methods for design-peculiar characteristics of several modules that make up the GPS receiver. It is believed that lower costs could be realized if the systems were redesigned by the engineering departments of the general-aviation manufacturers. However, the redesign was not attempted during this study so that the performance specified for the "Z" set could be maintained.

Table S-2. ACQUISITION COST OF LOW-PERFORMANCE AIRCRAFT GPS AVIONICS		
Equipment	Cost (Dollars) for Low-Performance Aircraft Avionics	
	Parametric Method	Accounting Method
Receiver	2,746	3,194
Control and Display	724	702
Antenna with Preamplifier	150	150
Total Cost	3,620	4,046

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

The Global Positioning System (GPS) is being developed for the military to provide, from a satellite-based positioning information system, accurate worldwide positioning capability that may have application as a navigation system for civil use.

As part of the ongoing program of the Federal Aviation Administration (FAA) to review new candidates for navigation, the Office of Systems Engineering Management (OSEM) is examining the GPS concept and has tasked ARINC Research Corporation, under Contract DOT-FA76WA-3788, to develop probable costs of civil GPS avionics.

This study addresses only issues relating to the economic feasibility of of a civil GPS concept by developing expected costs of avionics required for GPS operation.

1.2 PROJECT OVERVIEW

The objective of the analysis is to develop an independent assessment of the cost of avionics required to implement the GPS concept in the civil aviation community on the basis of designs being developed for the military. To meet this objective, it is necessary to analyze the various types of GPS avionics equipments being developed, identify the military-peculiar tactical requirements (e.g., high dynamics), and eliminate, where possible, military-peculiar capabilities that would not be required in civil applications.

ARINC Research Corporation developed the cost of civil GPS avionics using both the traditional accounting method of cost estimating and a parametric method based on a commercially available pricing model. This report presents the results of the evaluation, the constraints applied to ensure uniformity in the development of avionics costs, and a comparison of the results obtained by the two cost-estimating methods. The study results are presented in 1977 dollars, consistent with the technology and available data on which the estimates were based. Software development costs necessary for the GPS receiver operation have not been estimated

since it is believed that the software will have been developed under Government sponsorship before introduction of the system to civil applications.

1.3 ORGANIZATION OF THE REPORT

The six chapters of this report address the evaluated concept, describe the techniques used in estimating the costs of the system designs, and present the results of the evaluation.

Chapter Two identifies the GPS concept and defines the avionics considered in the evaluation.

Chapter Three identifies the two methodologies used in estimating costs of avionics.

Chapter Four presents the results of the evaluation using the parametric method of cost estimating.

Chapter Five presents the results of the evaluation using the accounting method of cost estimating.

Chapter Six presents the conclusions regarding the expected costs of GPS avionics, obtained by comparing the results of the two cost-estimating methods.

CHAPTER TWO

GLOBAL POSITIONING SYSTEM (GPS)
CIVIL AVIONICS

The military design that exhibits capabilities closest to that suitable for civil applications on a worldwide basis and incorporates area navigation (RNAV) capability is the medium-dynamic system referred to as the "Z" set. This set, designed for nontactical cargo aircraft and tactical bombers and tankers, has been chosen for cost comparison for civil applications. This design requires the minimum hardware modification when defining a civilian airborne GPS navigation set. However, it may not meet the minimum air navigation performance requirements for other than level flight because of the update rates, reacquisition times when transferring from one satellite to another, and other performance characteristics. Consideration of this design was mandated by the advanced state of development of the "Z" set, and the availability of data necessary for cost evaluation. The signal-format, signal-acquisition, and frequency-conversion techniques, as well as data processing and display, have been retained without modification to assure the same performance as will be provided by the original equipment. Where additional capability was incorporated in modules of the "Z" set, such as the detection of both the P and C/A codes, the capability was retained in the analysis. Packaging techniques and environmental considerations have been altered to reflect the particular requirements of the commercial air carriers and general aviation. This chapter describes the civil equivalent of the military "Z" set, identifying the packaging design modifications for both the high-performance and low-performance classes of aircraft.

2.1 HIGH-PERFORMANCE AIRCRAFT AVIONICS

The avionics required by high-performance aircraft using GPS as the navigation system consist of an antenna, preamplifier, receiver, and control and indicator panel (see Figure 2-1). The antenna is assumed to be similar to that developed for military applications. All equipments of the GPS system are based on definitions obtained from details in the critical design review report* and information provided by the engineering departments of the Space and Missile Systems Organization (SAMSO) and Magnavox.

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*NAVSTAR Global Positioning System, Phase I: ser Equipment, Set Z, Critical Design Review, 13 December 1977, Magnavox APS General Dynamics.

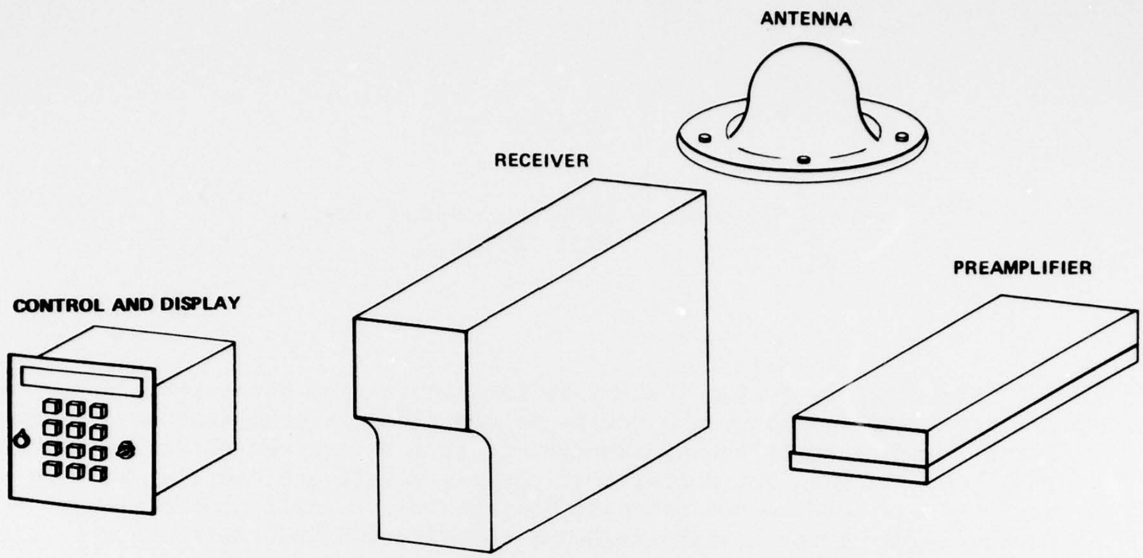

Figure 2-1. GPS AVIONICS FOR HIGH-PERFORMANCE AIRCRAFT

2.1.1 GPS Receiver

The "Z" set can be adapted to air carrier use by employing a standard 1/2 ATR short ARINC specification enclosure to house the 11 printed circuit boards and the RF assembly. Inputs to the receiver and outputs to the control and display device would be through a rear-mounted DPX connector. The boards constitute the receiver signal conditioning, the data processor, and the power supply with appropriate regulators. For evaluation purposes, none of the boards was redesigned or changed in physical appearance. However, the board-mounting technique and board-interconnect configuration were modified to reflect the standard practice of the airline industry. The component parts used in air carrier avionics meet the temperature requirements of military standards, although continuous unpressurized operation at high altitudes is not required. The resultant repackaged GPS receiver is less shock-proof than the original "Z" set counterpart but will meet the applicable environmental requirements of RTCA Document DO-160.

The oscillator, which provides the timing for the receiver, is a critical module of the electronic package. The oscillator chosen for the civil version of the GPS "Z" set is an oven-controlled unit with a stability of 5×10^{-8} correctable to 3×10^{-9} by use of a voltage controlled oscillator (VCO). Comparison with data in the critical design review shows this oscillator to be adequate in meeting the timing requirements of the "Z" set.

2.1.2 GPS Control and Display Unit

The control and display unit recommended for air carrier application is functionally identical and physically similar to the unit developed for military applications. Packaging requirements have been modified to reflect the normal practice of air carrier avionics manufacturing. The unit consists of eight 7-segment light-emitting diodes (LEDs), two 5 × 7 dot-matrix LEDs, 10 waypoint number readouts (including 0 for present position), keyboard for data entry, rotary data selector switch, and miscellaneous secondary control and indicator functions. However, the unit does not have a coarse deviation indicator (CDI); thus other flight instruments must be used to maintain proper bearing to position waypoints. An estimated position-error readout selectable as a control function can be used to assist in maintaining proper bearing. Four printed circuit boards included in the housing provide the necessary drivers, displays, control, power regulation, and interface with the receiver. The unit is designed for mounting in a prominent location on the forward pedestal of a flight deck.

2.1.3 GPS Preamplifier

The preamplifier required for GPS operations is a remotely mounted (at antenna), RFI-sealed, low-noise-figure device with bandpass cavity filters and an active gain stage. The active elements in the unit are powered through the RF cables from the GPS receiver. Packaging of the preamplifier is unrestricted since it is not mounted in standard racks or panels. However, the enclosure quality will have to be comparable to the military design unit, except that it will not require pressurization.

2.2 LOW-PERFORMANCE AIRCRAFT AVIONICS

The avionics required by low-performance aircraft using GPS as the navigation system consist of an antenna with built-in preamplifier, a remotely mounted receiver, and a console-mounted control and display unit. The design of the GPS system is based on details contained in the critical design review report, but with packaging practices of the general-aviation manufacturers consistent with the quality and functional features of the general-aviation community. This section identifies the design details of the receiver and the control unit. The antenna, with a built-in preamplifier, is assumed to be similar in complexity, and therefore in cost, to a unit developed for MLS applications. The GPS navigation package in typical general-aviation configuration is shown in Figure 2-2.

2.2.1 GPS Receiver

The GPS receiver expected to be used by single-engine and light twin-engine aircraft contains all the electronics required for signal conversion, frequency conversion, data processing, power supplies, and information generation to drive the display unit. The electronics will be mounted on plug-in printed circuit cards arranged to perform the receiver IF functions, processing, frequency synthesizing, and power supply regulation. Six plug-in cards, in addition to the enclosed RF module, are envisioned to perform

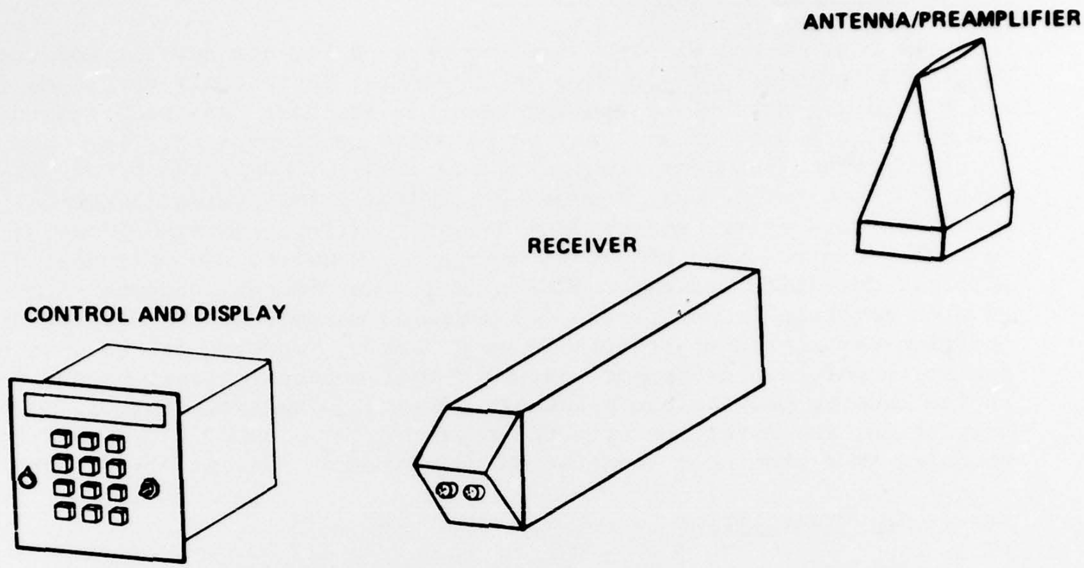

Figure 2-2. GPS AVIONICS FOR LOW-PERFORMANCE AIRCRAFT

all the functions detailed for the high-performance receiver. Because of lower shock and vibration requirements for general-aviation avionics, the cards can be larger and can accommodate more functions per card than their high-performance equivalents. A low-cost oscillator will be used -- one that meets the stability requirements of GPS oscillators but not the environmental requirements of high-performance units. The packaging of the receiver is unrestricted, typical of the enclosures and the practice of general-aviation manufacturers.

2.2.2 GPS Control and Display Unit

The control and display unit recommended for the low-performance general aviation aircraft is functionally identical to that described in Subsection 2.1.2, but the packaging and quality of components is consistent with the practice of the general-aviation manufacturers. The unit would be designed for installation in the flight console of aircraft for easy access and readability. Electronics required for lamp drivers, displays, input data processing, power regulation, and interface with the receiver would be mounted on four printed circuit cards housed in the unit.

CHAPTER THREE

COST-ESTIMATING METHODOLOGY

The equipment costs developed in this study will provide the basis for comparing various concepts intended to improve navigation accuracy in the next generation of Air Traffic Control (ATC) systems. Careful development of these data is an essential step in the overall analysis of the alternatives. To increase the probability of accurate cost estimating, two methods of pricing avionics costs are employed in the study: the parametric method, and the accounting method.* This chapter describes the two methods.

3.1 PARAMETRIC METHOD

The model chosen for the parametric method of pricing, the RCA Programmed Review of Information for Costing and Evaluation (PRICE), requires a set of parametric data inputs that properly define the module, or system, to be priced. The model was chosen because of its wide acceptance by military branches of the Federal Government as a computer-based pricing model. Of the many input parameters required, the most critical cost-driving ones are the weight, volume, and structural-electronic division; manufacturing complexities; and markups for overhead, G&A, and profit. Since manufacturing complexities vary among manufacturers in different fields (e.g., avionics for ARINC class or general-aviation class equipments), a detailed characterization is necessary for each manufacturer expected to produce avionic equipment.

ARINC Research has studied the manufacturing complexities of several key manufacturers of avionics by thoroughly reviewing existing avionics, collecting data at various avionics plants, and frequently exercising the PRICE model to establish the typical values for manufacturing complexities. To ensure accuracy in characterizations of existing equipment, all modules of a specific item of avionics were measured and weighed. The process was repeated on numerous types of avionics to enhance the accuracy of the parametric analyses.

The results were compiled and stored in ARINC Research data files, and they were used in estimating the cost of the avionics considered in this study.

*Both methods use common factors of 20 percent for General and Administrative expense and 10 percent for profit.

3.1.1 The PRICE Model

PRICE is a computerized parametric cost-modeling technique developed by RCA. It estimates development and production costs on the basis of physical and economic descriptors of the systems evaluated and compares new requirements with industry-wide data bases on analogous systems. PRICE efficiently stores, retrieves, and uses the historical information. Effective use of such empirical data allows classifying new designs by relating them to past similar design efforts. The method provides the means of reducing great quantities of empirical data to a relatively small number of principal variables that can be adjusted to match the economic and technological characteristics of the specific system.

3.1.2 Model Input Data

The model requires up to 40 parametric data inputs describing the physical and economic characteristics of the system or subassembly to be evaluated. When operated in the subassembly mode, the model requires similar inputs for all subassemblies and provides the means for final test and integration of the system. In general, the latter mode was employed for the cost estimates in this study.

The physical descriptors included such key features as weight of structure and electronics, packaging densities, volumes, quantities to be produced, manufacturing complexities, and degree of new design. Since the model is structured to provide a cost-per-pound based on densities and complexities, an accurate determination of the probable weight and volume of the subassembly being evaluated is essential.

The economic descriptors include such features as year of production, escalation rates, engineering schedules, production schedules, and management activities required during development and production. Schedules must be carefully selected because the final costs developed by the model are affected by the complexity of a product and the time allowed for its development and production. Other costs, such as those for management, tooling, or test equipment, have been normalized to the RCA data bank and are altered through sensitivity analyses and adaptation to specific manufacturers.

The key input parameters are listed in Table 3-1 in the format used throughout the study. Abbreviations and acronyms used are defined to provide an insight into the parametric data employed by the model. Appendix A provides a complete list of input parameters used by the model.

3.1.3 Model Output Data

The RCA PRICE model performs a series of evaluations based on the input parametric data and provides costs as a function of the elements associated with engineering and manufacturing for both development and production of a system or subassembly. Engineering costs include the cost of drafting, design, system management, project management, and data

Table 3-1. KEY PRICE PHYSICAL AND ECONOMIC DESCRIPTORS

Descriptor Acronym or Abbreviation	Description
QTY	Total quantity to be produced
WT	Weight of assembly (subassembly) in pounds
VOL	Volume of assembly (subassembly) in cubic feet
WS	Weight of structure (nonelectronic) of assembly in pounds
MCPLXS	Manufacturing complexity for structure
NEWST	Percent of new design required for structure
MCPLXE	Manufacturing complexity for electronics
NEWEL	Percent of new design required for electronics
CMPNTS	Number of electronic components
ECMPLX	Engineering complexity of assembly (subassembly)
PRMTH	Production period in months
LCURVE	Production learning curve
ECNE	Engineering change orders for electronics, in percent
ECNS	Engineering change orders for structure, in percent
YEAR	Year of technology (usual start of design/production)
ESC	Escalation rate in percent
PROJCT	Degree of project management support during engineering
DATA	Degree of data requirements
TLGTST	Degree of special tools and test equipment required for development
PLTFM	Factor for reliability testing, specification severity
SYSTEM	Degree of system engineering required
PPROJ	Degree of project management support during production
PDATA	Degree of data required during production
PTLGTS	Degree of special tools and test equipment required for production

documentation required during system development and production. The costs are presented for the entire production quantity for the development and production period on the basis of the data input parameter set; they include the effect of learning. Manufacturing is concerned primarily with the production of a system, but it also includes costs for prototype development and special tools or test equipment that might be required during development. As in the case of engineering, the output costs are for the entire production quantity with no escalation.

During program execution, the model frequently compares schedules, packaging densities, and other key input parameters with historical data in the RCA data banks. Abnormal inputs, such as too short development periods, are flagged and brought to the attention of the operator.

The output data sheet contains in the header all the information used as the parametric input to the model; it also provides the key parameters used in the derivation of the costs as a means to check the reasonableness of the results. Finally, the output data sheet provides the expected cost estimated by the program, bounded by approximately two-sigma level-of-confidence costs. The confidence intervals, although available from the model results, are omitted from this study to keep it similar to other economic analysis reports used in the evaluation of future ATC alternatives. A copy of a typical model output data sheet is provided in Appendix A.

3.2 ACCOUNTING METHOD

The technique chosen for an alternate cost evaluation is the industry standard accounting method of estimating production costs based on estimates of the numbers and types of piece parts. The method requires detailed bills of material and associated labor units, schematic diagrams, mechanical and electronic module layouts, and total quantity of units to be manufactured. Material costs are based on original equipment manufacturer (OEM) price lists in quantities of 1,000 or greater, and allowances are made for large parts procurements common to equipment manufacturers. Finally, the accounting structures of potential manufacturers must be known to allow for labor, overhead charges, quality control costs, general and administrative expenses, and the normal profits experienced in the avionics industry. This section presents the typical data inputs required in preparing cost-estimating worksheets and the rationalization for the development of the output data worksheets.

3.2.1 Input Data

The data necessary for the preparation of the accounting method of cost-estimating worksheets are usually taken directly from engineering bills of material. The component part numbers are identified and quantities entered on the worksheets. Procurement costs of the components are obtained either from OEM price lists or, in cases where the component is unique or in a high-cost category, through direct quotes provided by OEM distributors. Labor associated with fabrication or assembly of components is estimated in

terms of hours per 1,000 units in a mass production assembly line. Historical data maintained by most manufacturers provide the average labor estimates for both manual and automatic insertion processes. These data provide the average labor associated with assembly of components configured in a module (e.g., printed circuit card) or subassembly. The total labor hours are subjected to a comparative evaluation to determine the relative complexity of the assembly in comparison with the historical data. If the module is complex, in terms of having high component density or requiring printed circuit boards with multiple layers, a compensating complexity factor is applied to the labor estimate. The resultant material costs and labor estimates provide the data necessary for development of the cost-estimating output sheets.

3.2.2 Output Data

The worksheets used in developing total equipment costs are structured to provide cost information on individual modules (or subassemblies) and total avionics units. The rationalization for this method of presentation is to provide information that is useful in evaluating life-cycle costs where module stockage and associated costs are necessary for determining the recurring and nonrecurring logistics costs. Total avionics unit costs include unit assembly, test, and integration costs incurred when the avionics package is completed.

Costs are developed by considering the expense of materials, material handling charges, labor at either known or estimated hourly rates, average overhead obtained from a sampling of avionics manufacturers, and factory inspection costs during production. For air carriers only, an allowance of 25 percent of these direct costs is made to cover production engineering and quality control, resulting in the factory cost of the subassembly or avionics unit. The addition of general and administrative costs, together with a reasonable profit, provides the OEM or selling price of the unit. This is the cost expected to be paid by distributors handling the product or large fleet owners buying avionics at quantity prices. Private aircraft owners usually purchase avionics from distributors and pay an additional distributor handling markup of 30 percent for the ARINC quality units and 100 percent for the general-aviation quality units.

The output data sheets are also structured to permit easy reevaluation of the expected costs of avionics by substituting different labor, overhead, G&A, profit, and markup rates if there is sufficient concern over the data used or if a manufacturer prefers to use the exact factory rates rather than the average of the industry.

CHAPTER FOUR

PARAMETRIC METHOD OF AVIONICS COST DEVELOPMENT

Equipment costs were developed on subassembly levels and combined, by the PRICE model, to identify the expected cost of the GPS avionics. Two types of systems were estimated: the ARINC quality avionics intended for high-performance aircraft, and the general-aviation quality intended for the low-performance single-engine and twin-engine aircraft. This chapter presents the results of the evaluation by the parametric cost-estimating method and identifies the parameters used as inputs to the model.

Parameter values describing the physical configurations of each subassembly were obtained from information furnished by SAMSO and the Magnavox Corporation, while parameter values describing the proposed avionics manufacturers were extracted from the ARINC Research data bank. The data bank was compiled through extensive evaluations of existing avionics and calibration of the PRICE model to reflect the advertised costs of avionics available from avionics manufacturers.

4.1 AVIONICS COST DEVELOPMENT, HIGH-PERFORMANCE AIRCRAFT

4.1.1 GPS Receiver

The GPS receiver consists of 12 modules integrated into an enclosure and chassis. An oscillator complementing the 12 modules is mounted in the chassis, although its cost is treated as a separate item. Table 4-1 presents the physical and economic descriptors of the GPS receiver. Critical parameters, such as the electronic and structural complexity data, were derived by first reconstructing the military version of the "Z" set in PRICE terminology and exercising the model to obtain the cost data presented in the critical design review document.* The key parameters of the "Z" set were then compared with empirical RCA data files to identify the degree of higher or lower complexity than those in the ARINC Research files. As a final step, ARINC Research data were accordingly modified where more complex manufacturing practices were identified through the comparison of the "Z" set and empirical data. Economic descriptors used in the analysis are those which have been developed in past applications of the PRICE model to air carrier type avionics manufacturing.

**Ibid.*

Table 4-1. PARAMETER VALUES FOR GPS RECEIVER, HIGH-PERFORMANCE AIRCRAFT

Parameter	Processor Card	EPROM Card	Receiver I/O	Memory Control	Receiver Baseband	Receiver Control	C/A Code	CDU Interface	RF/IF Module	Synthesizer	RF Assembly	Power Supply	Enclosure and Chassis
	Parameter Value												
QTY	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
WT	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	1.0	1.0	0.422	8.826
VOL	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.01	0.03	0.03	0.005	0.212
WS	-	-	-	-	-	-	-	-	-	0.483	0.483	-	8.826
MCPLXS	-	-	-	-	-	-	-	-	-	6.341	6.341	-	6.141
NEWST	-	-	-	-	-	-	-	-	-	1	1	-	0.5
MCPLXE	8.606	8.817	7.789	8.12	8.926	7.726	8.104	7.331	8.951	8.167	8.253	7.445	-
NEWEL	1	1	1	1	1	1	1	1	1	1	1	0.5	-
CMPNTS	65	57	76	95	369	127	131	28	123	333	6	249	-
ECMPLX	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.5	1.5	0.9	0.9
PRMTH	36	36	36	36	36	36	36	36	36	36	36	36	36
LCURVE	0.865	0.865	0.865	0.865	0.865	0.865	0.865	0.865	0.865	0.865	0.865	0.865	0.865
ECNE	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	-
ECNS	-	-	-	-	-	-	-	-	-	0.01	0.01	-	0.01
YEAR	1977	1977	1977	1977	1977	1977	1977	1977	1977	1977	1977	1977	1977
ESC	0	0	0	0	0	0	0	0	0	0	0	0	0
PROJCT	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
DATA	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
TLGTST	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
PLTFM	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
SYSTEM	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
PPROJ	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
PDATA	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
PTLGTS	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3

Production quantities per manufacturer were set at 3,000 units over a three-year period to maintain a consistent base for comparison with other cost estimates developed for the FAA in the evaluation of alternatives. These quantities were considered sufficient to develop a typical avionics production learning curve and amortize development and start-up costs. The results of the analysis are presented in 1977 dollars with zero inflation over the period of development and manufacturing.

Table 4-2 summarizes the PRICE outputs by subassembly cost for development and production and gives cumulative costs. The oscillator module is considered a purchase item and not subject to manufacturer's development

Table 4-2. GPS RECEIVER, HIGH-PERFORMANCE AIRCRAFT (1977 DOLLARS)

Equipment	Cost Factors		
	Development (Dollars/Unit)	Production (Dollars/Unit)	Total (Dollars)
Processor Card	60.87	834.62	895
EPROM Card	70.57	1,015.69	1,086
Receiver I/O	41.78	406.78	449
Memory Control	51.95	545.77	598
Receiver Baseband	73.06	1,119.55	1,193
Receiver Control	39.97	384.69	425
C/A Coder	51.48	538.06	590
CDU Interface	35.09	271.25	306
RF/IF Module	81.69	1,149.73	1,231
Synthesizer	63.89	591.32	655
RF Assembly	67.09	632.37	699
Power Supply	17.35	223.75	241
Oscillator	-	225.00	225
Enclosure and Chassis	17.36	875.54	893
Test and Integration	9.64	316.63	326
Factory Sell Price	681.79	9,130.75	9,812
Distributor Markup (30 percent)			2,944
List Price			12,756

costs. The last equipment entry, Test and Integration, is a mandatory input when a system cost is developed by subassemblies. Test and Integration accounts for the final assembly of a unit, machining of interface components, provision of power connections, alignment and tuning of electrical subsystems, and performance of the final functional test of the system. (Software development and processor programming, necessary for the GPS receivers, are not included in the costs developed in this study.*) The factory price is the cost of manufacturing with appropriate G&A and profit included; it is the expected selling price to air carriers and distributors. The selling (list) price is the normal cost to owners of private aircraft buying limited quantities of high-performance aircraft product.

4.1.2 GPS Control and Display

The control and display unit consists of four subassemblies housed in an enclosure designed for mounting in pedestals of large aircraft flight decks. Table 4-3 presents the physical and economic descriptors required by the PRICE model for evaluation of the control and display unit. The same procedure used for the GPS receiver has been followed in developing critical parametric data for the unit. Enclosure and chassis data were developed from information for similar control units documented in ARINC Research data banks.

Table 4-4 gives the results of the PRICE evaluation. Production quantities are consistent with the assumption that only one unit will be required with each receiver.

4.1.3 GPS Preamplifier

The preamplifier required for GPS operation is a remotely mounted (at antenna), RFI-sealed, low-noise-figure device with bandpass cavity filters and an active gain stage. The unit receives power for the active elements through the RF cables from the GPS receiver. The PRICE parametric data descriptors class the unit as predominantly a structural device, and it has been evaluated as a single assembly. Economic parameters used are the same as those applied to the receiver and control assemblies. The results of the PRICE analysis of the preamplifier for production quantities of 3,000 units are given in the summary table of the GPS avionics system cost.

4.1.4 GPS Antenna

The antenna required for GPS operation by high-performance aircraft is assumed to be the same as that used by the military in deploying the "Z" set. Costs used in this study are those proposed by Magnavox to SAMSO except as affected by application of a learning curve for large production quantity.

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*The assumption is that the U.S. Government will have underwritten these costs by the time production begins.

Table 4-3. PARAMETER VALUES FOR CONTROL AND DISPLAY, HIGH-PERFORMANCE AIRCRAFT

Parameter	Parameter Value				
	Regulator	Display Board	Driver Board	Control Board	Enclosure and Chassis
QTY	3000	3000	3000	3000	3000
WT	0.233	0.234	0.234	0.234	2.785
VOL	0.008	0.003	0.003	0.003	0.082
WS	-	-	-	-	2.785
MCPLXS	-	-	-	-	6.294
NEWST	-	-	-	-	0.8
MCPLXE	7.056	7.791	7.755	8.239	-
NEWEL	0.3	1	1	1	-
CMPNTS	6	19	42	41	-
ECMPLX	0.4	0.9	0.7	1.0	0.9
PRMTH	36	36	36	36	36
LCURVE	0.865	0.865	0.865	0.865	0.865
ECNE	0.01	0.01	0.09	0.12	-
ECNS	-	-	-	-	0.03
YEAR	1977	1977	1977	1977	1977
ESC	0	0	0	0	0
PROJCT	0.5	0.5	0.5	0.5	0.5
DATA	0.5	0.5	0.5	0.5	0.5
TLGTST	0.3	0.3	0.3	0.3	0.3
PLTFM	1.7	1.7	1.7	1.7	1.7
SYSTEM	0.3	0.3	0.3	0.3	0.3
PPROJ	0.5	0.5	0.5	0.5	0.5
PDATA	0.5	0.5	0.5	0.5	0.5
PTLGTS	0.3	0.3	0.3	0.3	0.3

4.1.5 Cost Summary

The cost of avionics required by high-performance aircraft for implementation of the GPS navigation system is given in Table 4-5. The cost factors shown are the total development dollars for each piece of avionics and the per unit production costs of the equipment as computed by the PRICE model. The "Total" column gives the production cost and development cost amortized over 3,000 units of production. The factory price is the expected cost of a single (nonredundant) system purchased by an air carrier or

Table 4-4. GPS CONTROL AND DISPLAY, HIGH-PERFORMANCE AIRCRAFT (1977 DOLLARS)			
Equipment	Cost Factors		
	Development (Dollars/Unit)	Production (Dollars/Unit)	Total (Dollars)
Regulator	2.70	95.43	98
Display Board	23.35	190.73	214
Driver Board	19.24	181.62	201
Control Board	35.69	282.41	318
Enclosure and Chassis	9.64	392.62	402
Test and Integration	1.75	64.86	67
Factory Sell Price	92.37	1,207.67	1,300
Distributor Markup (30 percent)			390
List Price			1,690

Table 4-5. GPS AVIONICS, HIGH-PERFORMANCE AIRCRAFT, SINGLE SYSTEM (1977 DOLLARS)			
Equipment	Cost Factors		
	Development* (Dollars)	Production (Dollars/Unit)	Total (Dollars/Unit)
Receiver	2,045,370	9,131	9,812
Control and Display	277,110	1,208	1,300
Preamplifier	170,597	671	727
Antenna	75,000	205	230
Factory Sell Price	2,568,077	11,215	12,069
Distributor Markup (30 percent)			3,621
List Price			15,690

*Development costs assumed amortized over 3,000-unit production quantity.

distributors. The list price includes a markup for distribution and is the expected cost to single aircraft owners requiring high-performance avionics.

4.2 AVIONICS COST DEVELOPMENT, LOW-PERFORMANCE AIRCRAFT

4.2.1 GPS Receiver

The receiver consists of seven subassemblies housed in an enclosure and chassis. An oscillator module complementing the subassemblies is mounted in the chassis, but this is not included in the chassis cost. Table 4-6 gives the physical and economic descriptors of the GPS receiver. Critical

Table 4-6. PARAMETER VALUES FOR GPS RECEIVER, LOW-PERFORMANCE AIRCRAFT

Parameter	Parameter Value							
	Receiver	Processor #1	Processor #2	Processor #3	Synthesizer	RF Module	Power Supply	Enclosure and Chassis
QTY	3000	3000	3000	3000	3000	3000	3000	3000
WT	0.63	0.63	0.63	0.63	0.48	0.48	0.4	3.0
VOL	0.023	0.023	0.023	0.023	0.008	0.008	0.005	0.203
WS	-	-	-	-	0.1	0.1	0.005	3.0
MCPLXS	-	-	-	-	4.321	4.321	4.321	4.68
NEWST	-	-	-	-	0.1	0.1	0.1	0.2
MCPLXE	6.037	6.299	6.299	6.299	6.788	6.037	5.714	-
NEWEL	1	1	1	1	0.7	0.7	0.3	-
CMPNTS	228	387	295	236	186	81	31	-
ECMPLX	1.0	1.5	1.0	0.9	0.7	0.7	0.4	0.3
PRMTH	36	36	36	36	36	36	36	36
LCURVE	0.865	0.865	0.865	0.865	0.865	0.865	0.865	0.865
ECNE	0.05	0.05	0.05	0.05	0.05	0.05	0.005	-
ECNS	-	-	-	-	0.005	0.005	0.005	0.01
YEAR	1977	1977	1977	1977	1977	1977	1977	1977
ESC	0	0	0	0	0	0	0	0
PROJCT	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
DATA	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
TLGTST	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
PLTFM	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
SYSTEM	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
PPROJ	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
PDATA	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
PTLGTS	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

parameters, such as electronic and structural complexity data, were developed in comparison with RCA empirical data and with ARINC Research data files for typical general-aviation avionics, and appropriate corrective upgrading was applied to reflect the degree of complexity associated with GPS. The economic descriptors used in the analysis are those developed in past applications of the PRICE model for this class of avionics manufacturing.

The results of the PRICE analysis of the low-performance GPS receiver are shown in Table 4-7. The development costs are shown for each module; they have been amortized over a production quantity of 3,000 units. The oscillator is considered to be an outside-purchased item, not requiring development. Test and integration costs reflect the expense of final assembly and factory testing of the completed GPS receiver. The factory sell price is the cost to distributors handling the product. A typical distributor markup of 100 percent has been applied to the sell price to estimate the list price, which private aircraft owners would pay for a GPS receiver.

Table 4-7. GPS RECEIVER, LOW-PERFORMANCE AIRCRAFT (1977 DOLLARS)

Equipment	Cost Factors		
	Development (Dollars/Unit)	Production (Dollars/Unit)	Total (Dollars)
Receiver	21.98	109.37	131
Processor #1	55.07	232.45	287
Processor #2	23.38	137.38	161
Processor #3	23.38	137.38	161
Synthesizer	13.30	144.59	158
RF Module	11.21	78.81	90
Oscillator	-	118.57	119
Power Supply	3.61	54.21	58
Enclosure and Chassis	1.12	110.29	111
Test and Integration	2.49	94.59	97
Factory Sell Price	155.54	1,217.64	1,373
Distributor Markup			1,373
List Price			2,746

4.2.2 GPS Control and Display

The control unit consists of four subassemblies housed in an enclosure designed for mounting in the aircraft control panel. Table 4-8 presents the physical and economic descriptors required by the PRICE model for evaluation of the control and display unit. The same procedure as that used for the receiver has been followed in developing critical parametric data for the control and display unit. Enclosure and chassis data were developed from information related to similar units documented in ARINC Research data banks.

Table 4-8. PARAMETER VALUES FOR CONTROL AND DISPLAY, LOW-PERFORMANCE AIRCRAFT

Parameter	Parameter Value				
	Regulator	Display Board	Driver Board	Control Board	Enclosure and Chassis
QTY	3000	3000	3000	3000	3000
WT	0.233	0.234	0.234	0.234	1.785
VOL	0.008	0.003	0.003	0.003	0.082
WS	-	-	-	-	1.785
MCPLXS	-	-	-	-	4.833
NEWST	-	-	-	-	0.8
MCPLXE	5.288	6.023	5.967	6.471	-
NEWEL	0.3	1	1	1	-
CMPNTS	6	19	42	41	-
ECMPLX	0.4	0.9	0.7	1.0	0.9
PRMTH	36	36	36	36	36
LCURVE	0.865	0.865	0.865	0.865	0.865
ECNE	0.01	0.05	0.05	0.06	-
ECNS	-	-	-	-	0.05
YEAR	1977	1977	1977	1977	1977
ESC	0	0	0	0	0
PROJCT	0.3	0.3	0.3	0.3	0.3
DATA	0.3	0.3	0.3	0.3	0.3
TLGTST	0.2	0.2	0.2	0.2	0.2
PLTFM	1.6	1.6	1.6	1.6	1.6
SYSTEM	0.3	0.3	0.3	0.3	0.3
PPROJ	0.3	0.3	0.3	0.3	0.3
PDATA	0.3	0.3	0.3	0.3	0.3
PTLGTS	0.2	0.2	0.2	0.2	0.2

The results of the evaluation appear in Table 4-9. Production quantities are based on the assumption that only one unit will be required with each receiver. The list price shown includes the normal markup for distribution and is the expected cost to private aircraft owners.

Table 4-9. CONTROL AND DISPLAY, LOW-PERFORMANCE AIRCRAFT (1977 DOLLARS)

Equipment	Cost Factors		
	Development (Dollars/Unit)	Production (Dollars/Unit)	Total (Dollars)
Regulator	1.76	25.28	27
Display Board	16.60	48.77	65
Driver Board	13.60	46.53	60
Control Board	19.94	71.29	91
Enclosure and Chassis	4.84	85.00	90
Test and Integration	0.76	28.05	29
Factory Sell Price	57.50	304.92	362
Distributor Markup			362
List Price			724

4.2.3 Cost Summary

The cost of avionics required by low-performance aircraft for implementation of the GPS navigation system is presented in Table 4-10. Total development costs, unit production costs, and factory sell prices with

Table 4-10. GPS AVIONICS, LOW-PERFORMANCE AIRCRAFT, SINGLE SYSTEM (1977 DOLLARS)

Equipment	Cost Factors		
	Development* (Dollars)	Production (Dollars/Unit)	Total (Dollars/Unit)
Receiver	466,620	1,218	1,373
Control and Display	172,500	305	362
Antenna with Preamplifier	15,000	70	75
Factory Sell Price	654,120	1,593	1,810
Distributor Markup			1,810
List Price			3,620

*Development costs assumed amortized over 3,000-unit production quantity.

development amortized over the 3,000-unit production quantity are shown for the three subsystems making up the GPS concept. The cost of the antenna with built-in preamplifier is based on a similar system recently developed for general-aviation application. The list price of $3,620 per aircraft is the expected acquisition cost to single-engine and light twin-engine aircraft owners to obtain the navigational capability defined by the military "Z" set.

CHAPTEк FIVE

ACCOUNTING METHOD OF AVIONICS COST DEVELOPMENT

Equipment costs were developed on subassembly levels and combined to identify the expected cost of the avionics. As in the parametric method of cost estimating, documented in Chapter Four, both the high-performance and low-performance aircraft avionics were estimated. This chapter presents the results of the accounting method. Information necessary to describe the equipment was obtained from SAMSO and the Magnavox Corporation. The latter provided a production bill of material on the "Z" set. This bill of material is the dominant driver in developing costs of subassemblies, although some latitude was taken to eliminate military specifications and replace components with similar-function but lower cost components. In all cases where substitutions were made the components chosen met the environmental specifications of DO-160 of the Radio Technical Commission for Aeronautics (RTCA).

5.1 AVIONICS COST DEVELOPMENT, HIGH-PERFORMANCE AIRCRAFT

5.1.1 GPS Receiver

The GPS receiver consists of 12 modules integrated into an enclosure and chassis. The RF assembly, which constitutes the 12th module, is integrated in the RF/IF subassembly. An oscillator complementing the 12 modules is mounted in the chassis, although its cost is treated as a purchased item rather than one produced by the avionics manufacturer. Table 5-1 presents cost development of the subassemblies based on material and labor estimates of each subassembly. Detailed parts lists and labor data are presented in Appendix B of this report. A material-handling charge of 25 percent of material cost is added to cover inventory management and component testing before delivery to the assembly lines. The labor rate of $13 per hour combined with a 135 percent overhead reflects the average 1977 hourly rate of several avionics manufacturers. The selling price indicated in Table 5-1 is the expected cost of the subassembly to distributors and large fleet owners, such as the commercial air carriers. Small fleet owners and private owners of high-performance aircraft must purchase avionics from distributors, who increase the cost 30 percent over the list price. The assembly and test cost column reflects the cost of integrating the subassemblies into a working avionics unit and the cost associated with burn-in and final testing of the unit to ensure operational readiness. The total cost of the receiver, $8,811, is the expected factory selling price without the antenna, preamplifier, or controls.

Table 5-1. GPS RECEIVER COST DEVELOPMENT, HIGH-PERFORMANCE AIRCRAFT (1977 DOLLARS)

Cost Element	Module Cost in Dollars													
	CDU I/O	CPU	Memory Control	Memory	Receiver I/O	C/A Coder	Receiver Control	Baseband	RF/IF	Synthesizer	Power Supply	Chassis	Assembly and Test	Totals
Material Cost	45.04	149.38	264.20	324.54	112.28	225.45	145.49	416.15	308.69	251.83	120.15	313.25	-	2,676.45
Material Handling (25%)	11.26	37.35	66.05	81.40	28.07	56.36	36.37	104.04	77.17	62.96	30.04	54.31*	-	645.38
Labor ($13.00/Hour)	26.52	30.65	50.75	33.62	37.13	46.36	46.36	77.61	134.36	76.67	41.60	64.94	57.07	723.64
Burden (135% Labor)	35.80	41.38	68.52	45.38	50.12	62.58	62.58	104.77	181.38	103.51	56.16	87.66	77.04	976.88
Inspection (5% Labor and Burden)	3.12	3.60	5.96	3.95	4.36	5.45	5.45	9.12	15.79	9.01	4.89	7.63	6.71	85.04
Subtotal	121.74	262.36	455.48	488.89	231.96	396.20	296.25	711.69	717.39	503.98	252.84	527.79	140.82	5,107.39
Engineering and QC (25%)	30.44	65.59	113.87	122.22	57.99	99.05	74.06	177.92	179.35	126.00	63.21	131.95	35.20	1,276.85
Factory Cost	152.18	327.95	569.35	611.11	289.95	495.25	370.31	889.61	896.74	629.98	316.05	659.74	176.02	6,384.24
G&A (20%)	30.44	65.59	113.87	122.22	57.99	99.05	74.06	177.92	179.35	126.00	63.21	131.95	35.20	1,276.85
Total Direct Cost	182.62	393.54	683.22	733.33	347.94	594.30	444.37	1,067.53	1,076.09	755.98	379.26	791.69	211.22	7,661.09
Profit (15%)	27.39	59.53	102.48	110.00	52.19	89.15	66.66	160.13	161.41	113.40	56.90	118.75	31.68	1,149.67
Selling Price	210.01	453.07	785.70	843.33	400.13	683.45	511.03	1,227.66	1,237.50	869.38	436.16	910.44	242.90	8,810.76
Distribution (30%)														2,643.23
List Price														11,453.99

*Material handling of the oscillator, that is included in the chassis module, is at 10 percent rate.

5.1.2 GPS Control and Display

The control and display unit consists of four subassemblies housed in an enclosure designed for mounting in pedestals of large aircraft flight decks. Table 5-2 presents the cost development of the subassemblies based on material and labor estimates of each subassembly. Detailed parts lists and labor data are presented in Appendix B. The development of unit cost is the same as described for the receiver in the preceeding Subsection 5.1.1. The selling price of $1,223 reflects the cost of final assembly and testing and is the expected cost of acquisition by distributors and large fleet owners.

5.1.3 GPS Preamplifier

The preamplifier required for GPS operations is a remotely mounted (at antenna), RFI-sealed, low-noise-figure device with band pass cavity filters and an active gain stage. Table 5-3 presents the cost development of the preamplifier based on material and labor estimates identified in Appendix B. Packaging of the preamplifier is unrestricted since it is mounted in the frame of an aircraft, and not in either standard electronics bays or control consoles.

5.1.4 GPS Antenna

The cost of the antenna was assumed to be the same as in Chapter Four.

5.1.5 Cost Summary

The cost of avionics required by high-performance aircraft for implementation of the GPS navigation system is given in Table 5-4. The cost factors shown are the per unit production costs of the equipment, assuming large-quantity manufacturing (i.e., 1,000 units per year). System development costs and production tooling costs are not included. The list price includes a markup of 30 percent for distribution and is the expected cost to single aircraft owners requiring high-performance avionics.

5.2 AVIONICS COST DEVELOPMENT, LOW-PERFORMANCE AIRCRAFT

5.2.1 GPS Receiver

The receiver consists of seven subassemblies housed in an enclosure and chassis. An oscillator module complementing the subassemblies is mounted in the chassis. Table 5-5 presents the cost development of each subassembly and total unit cost. The total cost includes final assembly and functional testing of the receiver. Subassembly costs are based on material and labor estimates documented in Appendix B. Materials are either the commercial equivalents of components identified in the Magnavox production bill of material or lower-cost functional equivalents commonly used in general-aviation equipments (e.g., microprocessors). The Factory Sell Price of $1,597 is the cost of manufacturing a GPS receiver in large quantities with

Table 5-2. GPS CONTROL AND INDICATOR COST DEVELOPMENT, HIGH-PERFORMANCE AIRCRAFT (1977 DOLLARS)

Cost Element	Module Cost in Dollars						
	Display	Driver	Control	Power Supply	Enclosure and Chassis	Assembly and Test	Totals
Material Cost	52.33	82.76	106.56	23.53	60.75	-	325.93
Material Handling (25%)	13.08	20.69	26.64	5.88	15.19	-	81.48
Labor ($13.00/Hour)	17.54	19.73	20.40	15.74	20.12	28.60	122.13
Burden (135% Labor)	23.67	26.64	27.54	21.25	27.17	38.61	164.88
Inspection (5% Labor and Burden)	2.06	2.32	2.40	1.85	2.36	3.36	14.35
Subtotal	108.68	152.14	183.54	68.25	125.59	70.57	708.77
Engineering and QC (25%)	27.17	38.03	45.89	17.06	31.40	17.64	177.19
Factory Cost	135.85	190.17	229.43	85.31	156.99	88.21	885.96
G&A (20%)	27.17	38.03	45.89	17.06	31.40	17.64	177.19
Total Direct Cost	163.02	228.20	275.32	102.37	188.39	105.85	1,063.15
Profit (15%)	24.45	34.23	41.30	15.36	28.26	15.88	159.48
Selling Price	187.47	262.43	316.62	117.73	216.65	121.73	1,222.63
Distribution (30%)							366.79
List Price							1,589.42

Table 5-3. GPS PREAMPLIFIER COST DEVELOPMENT, HIGH-PERFORMANCE AIRCRAFT (1977 DOLLARS)	
Cost Element	Dollar Amount
Material Cost	215.85
Material Handling (25%)	53.96
Labor ($13.00/Hour)	56.91
Burden (135% Labor)	76.83
Inspection (5% Labor and Burden)	6.69
Subtotal	410.24
Engineering and QC (25%)	102.56
Factory Cost	512.80
G&A (20%)	102.56
Total Direct Cost	615.36
Profit (15%)	92.30
Selling Price	707.66
Distribution (30%)	212.30
List Price	919.96

G&A and profit included. This is the expected purchase price to distributors who resell to aircraft owners.

5.2.2 GPS Control and Display

The control unit consists of four subassemblies housed in an enclosure designed for mounting in the aircraft control panel. Table 5-6 presents the cost development of the subassemblies and the total cost of the unit, including final assembly and testing. Material and labor estimates used in the cost development are documented in Appendix B. The "Selling Price" of $351 is the expected cost of the control and display unit to equipment distributors.

Table 5-4. GPS AVIONICS, HIGH-PERFORMANCE AIRCRAFT, SINGLE SYSTEM (1977 DOLLARS)	
Equipment	Dollar Amount
Receiver	8,811
Control and Display	1,223
Preamplifier	708
Antenna	230
Factory Sell Price	10,972
Distributor Mark-Up	3,290
List Price	14,262

5.2.3 Cost Summary

The cost of avionics required by low-performance aircraft for implementation of the GPS navigation system is presented in Table 5-7. The cost of the antenna with built-in preamplifier is based on a similar system recently developed for general-aviation application. Cost data on all equipments making up the GPS navigation system are based on production quantities typical of the general-aviation manufacturers when new systems are introduced. Development costs are normally included in the factory prices and amortized over the large production quantities typical of the general-aviation manufacturer. Software development and chip programming costs have not been included in this analysis.

Table 5-5. GPS RECEIVER COST DEVELOPMENT, LOW-PERFORMANCE AIRCRAFT (1977 DOLLARS)

Cost Element	Module Cost in Dollars										
	Receiver	Processor 1	Processor 2	Processor 3	RF/IF	Synthesizer	Power Supply	Enclosure and Chassis	Oscillator	Assembly and Test	Totals
Material Cost	201.89	229.08	64.60	96.61	32.34	87.74	18.19	24.10	71.40	-	825.95
Material Handling (10%)	20.19	22.91	6.46	9.66	3.23	8.77	1.82	2.41	7.14	-	82.59
Labor ($4.00/Hour)	21.94	13.75	9.12	13.21	8.43	15.17	4.10	9.63	-	10.50	105.85
Burden (135% Labor)	29.62	18.56	12.31	17.84	11.38	20.48	5.53	13.00	-	14.18	142.90
Subtotal	273.64	284.30	92.49	137.32	55.38	132.16	29.64	49.14	78.54	24.68	1,157.29
G&A (20%)	54.73	56.86	18.50	27.46	11.08	26.43	5.91	9.83	15.71	4.94	231.35
Total Direct Cost	328.37	341.16	110.99	164.78	66.46	158.59	35.45	58.97	94.25	29.62	1,388.64
Profit (15%)	49.26	51.17	16.65	24.72	9.97	23.79	5.32	8.85	14.14	4.44	208.31
Selling Price	377.63	392.33	127.64	189.50	76.43	182.38	40.77	67.82	108.39	34.06	1,596.95
Distribution (100%)											1,596.95
List Price											3,193.90

Table 5-6. GPS CONTROL AND INDICATOR COST DEVELOPMENT, LOW-PERFORMANCE AIRCRAFT (1977 DOLLARS)

Cost Element	Module Cost in Dollars						
	Display	Driver	Control	Power Supply	Enclosure and Chassis	Assembly and Test	Totals
Material Cost	19.33	35.83	58.38	10.93	26.96	-	151.43
Material Handling (10%)	1.93	3.58	5.84	1.09	2.70	-	15.14
Labor ($4.00/Hour)	5.40	6.07	6.28	3.67	6.69	9.10	37.21
Burden (135% Labor)	7.28	8.20	8.47	4.96	9.03	12.29	50.23
Subtotal	33.94	53.68	78.97	20.65	45.38	21.39	254.01
G&A (20%)	6.79	10.74	15.79	4.13	9.08	4.28	50.81
Total Direct Cost	40.73	64.42	94.76	24.78	54.46	25.67	304.82
Profit (15%)	6.11	9.66	14.21	3.72	8.17	3.85	45.72
Selling Price	46.84	74.08	108.97	28.50	62.63	29.52	350.54
Distribution (100%)	46.84	74.08	108.97	28.50	62.63	29.52	350.54
List Price	93.68	148.16	217.94	57.00	125.26	59.04	701.08

Table 5-7. GPS AVIONICS, LOW-PERFORMANCE AIRCRAFT, SINGLE SYSTEM (1977 DOLLARS)

Equipment	Cost
Receiver	1,597
Control and Display	351
Antenna with Preamplifier	75
Factory Sell Price	2,023
Distributor Mark-Up	2,023
List Price	4,046

CHAPTER SIX

RESULTS OF EVALUATION

This study has developed costs of avionics on the basis of a uniform parametric approach to estimating costs with the assistance of a pricing model. Concurrently, an accounting method of cost estimating was employed to provide additional confidence in the results through comparison of the costs developed by the parametric method with costs developed by the traditional cost-estimating methods. The system data used in both analyses were provided by SAMSO and Magnavox, the developers of the GPS concept; the production data were developed through detailed analyses of several leading avionics manufacturers producing either high-performance aircraft equipment or low-performance aircraft equipment. This chapter summarizes the results of the evaluation of the GPS concept and compares the results obtained through the parametric cost-estimating method with those obtained through the accounting cost-estimating method.

6.1 CONCEPT EVALUATED

The adaptation of the military-developed "Z" set as a candidate for civil application of GPS has resulted in a navigation system that will provide positioning information to aircraft in flight as well as the functional capabilities equivalent to an area navigation (RNAV) system. No attempt was made in this analysis to ascertain whether the "Z" set meets the civil requirements of a navigational system. The "Z" set was chosen for analysis because of the advanced development status of the system, which was sufficiently detailed to permit adaptation to civil applications. The results developed in this analysis provide insight into the probable cost of civil avionics based on the performance specifications of the military "Z" set.

6.2 COST OF CONCEPT EVALUATED

The avionics costs for high-performance aircraft developed by application of the parametric and accounting methods are summarized in Table 6-1. The values indicate the probable selling price per item of avionics to the air carriers and to high performance general-aviation aircraft owners. Appropriate markups for distribution have been included in the general-aviation totals on the basis of known or expected practices of the avionics manufacturers. All costs are based on the 1977 dollar without inflation.

Table 6-1. ACQUISITION COST OF HIGH-PERFORMANCE AIRCRAFT GPS AVIONICS

Equipment	Cost (Dollars) by User Category					
	Parametric Method				Accounting Method	
	Development Only	Production Only	Air Carrier*	General* Aviation	Air Carrier	General Aviation
Receiver	681	9,131	9,812	12,756	8,811	11,454
Control and Display	92	1,208	1,300	1,690	1,223	1,589
Preamplifier	56	671	727	945	708	920
Antenna	25	205	230	299	230	299
Total Cost	854	11,215	12,069	15,690	10,972	14,262

*Includes development costs.

The total cost of the GPS navigation system acquisition for a user category appears to be different depending on the cost-estimating method used. However, the parametric method includes development and production tooling whereas the accounting method does not. On the basis of production costs only the two techniques provide expected system costs that vary by 2 percent.

The avionics costs for low-performance aircraft developed by the two methods of cost estimating are summarized in Table 6-2. Since development costs are considered in both techniques, a direct comparison of results is possible. The 12 percent increase in system costs experienced in the results of the accounting method are traceable to the design of subassemblies and the associated parts lists supporting the design, as provided by Magnavox. Both the receiver module and the frequency synthesizer are considered overdesigned for the intended application since they contain provisions for both the P code and C/A code of GPS. Since the accounting method is dependent on the bill of material, which includes components necessary for detection of both codes, a slightly higher manufacturing cost can be anticipated. Redesign of these units by general-aviation manufacturers would eliminate the P code provisions and reduce the cost of these subassemblies so that the results would compare more closely with the results of the parametric method. The detailed design of the GPS receiver was intentionally not altered so that performance comparable to that specified for the military "Z" set would be ensured.

Table 6-2. ACQUISITION COST OF LOW-PERFORMANCE AIRCRAFT GPS AVIONICS		
Equipment	Cost (Dollars) for Low-Performance Aircraft Avionics	
	Parametric Method	Accounting Method
Receiver	2,746	3,194
Control and Display	724	702
Antenna with Preamplifier	150	150
Total Cost	3,620	4,046

APPENDIX A

RCA PRICE MODEL INPUT PARAMETERS

This appendix presents a listing of the input parameters used by the RCA PRICE model. Figure A-1 is a typical input worksheet and Figure A-2 is an example of a typical model output data sheet.

PRICE System
Input Worksheet

RCA Government and Commercial Systems

Item: EPROM CARD

Date

General	QTY	PROTOS	WT	VOL	MODE
	3000	3	.601	.0144	1
	QTYSYS	INTEGE	INTEGS	AMULTE (%)	AMULTM (%)
	1	.3	.3	138000	138000
Mechanical/Structural	WS	MCPLXS	PRODS	NEWST	DESRPS
	.001	6.2	0	0	0
Electronics	USEVOL	MCPLXE	PRODE	NEWEL	DESRPE
	.99	8.817	0	1.0	2
	PWR	CMPINT	CMPID	PWRFAC	CMPEFF
	6.0	57	0	0	0
Engineering	ENMTHS	ENMTHP	ENMTHD	ECMPLX	PRNF
	1	12	14	1.0	.3
Production	PRMTHS	PRMTHP	ECURVE	ECNT	ECNS
	12	48	.865	.01	.01
Purchased Item (Mode 3)	WS	BVCOST	ECURVE		
GFE (Mode 4)	WS	MCPLXE	MCPLXS		
Additional Data (Modes 9 & 10)	MCONST	MEXP	WECF	TARCST (Mode 10 only)	
Global	YEAR	ESC	PROJCT	DATA	TLGTST
	1977	0	.5	.5	.3
	PLTFM	SYSTEM	PPROJ	PDATA	PTLGTS
	1.7	.3	.5	.5	.3

MODES

[illegible] 6 MODIFIED PUR. ITEM
[illegible] 7 MODIFIED GFE ITEM
[illegible] 8 PARASYN
[illegible] 9 E M ITEM CALC WT & VOL
4 GFE ITEM 10 GEOSYN
5 INTEG & TEST

Notes:

GC 1595 2/75

Figure A-1. TYPICAL INPUT WORKSHEET

```
PROCESSOR EPROM

INPUT DATA

ELECTRONICS
USEVOL  0.990 MCPLXE  8.817 PRODE   0.000 NEWEL    1.000 DESRPE   2.000
PWR     6.000 CMPNTS    57. CMPID   0.000 PWRFAC   0.000 CMPEFF   0.000

ENGINEERING
ENMTHS    1.0 ENMTHP   12.0 ENMTHT   14.0 ECMPLX   1.000 PRNF     0.300

PRODUCTION
PRMTHS   12.0 PRMTHF   48.0 LCURVE  0.865 ECNE     0.010 ECNS     0.010

GLOBAL
YEAR    1977. ESC     0.00% PROJCT  0.500 DATA     0.500 TLGTST   0.300
PLATFM  1.700 SYSTEM  0.300 PPROJ   0.500 PDATA    0.500 PTLGTS    0.30

PROGRAM COST              DEVELOPMENT        PRODUCTION        TOTAL COST
ENGINEERING
 DRAFTING                      40475.              433.            40908.
 DESIGN                       134050.             1467.           135517.
 SYSTEMS                        5461.                0.             5461.
 PROJ MGMT                      9441.            74544.            83985.
 DATA                           2565.             3090.             5655.
  SUBTOTAL(ENG)               191992.            79534.           271525.

MANUFACTURING
 PRODUCTION                        0.          2870753.          2870753.
 PROTOTYPE                     18737.                0.            18737.
 TOOL-TEST EQ                    969.            96777.            97745.
  SUBTOTAL(MFG)                19706.          2967530.          2987235.

  TOTAL COST                  211697.          3047064.          3258761.

VOL       0.014 AVCOST  956.92 TOTAL AV PROD COST 1015.69 LCURVE  0.865
WT        0.601 ECNE     0.010 ECNS     0.010 DESRPE 0.159 DESRPS  0.000

MECH/STRUCT
WS        0.001 WSCF     0.069 MECID    0.000 PRODS  6.525 MCPLXS  6.200
ELECTRONICS
WE        0.600 WECF    42.088 CMPID    0.000 PRODE  4.847 MCPLXE  8.817
PWR       6.000 CMPNTS     57.                PWRFAC 0.565 CMPEFF  3.550

SCHEDULES
ENMTHS    1.000 ENMTHP  12.000 ENMTHT 14.000 ECMPLX 1.000 PRNF     0.300
PRMTHS   12.000 PRMTHF  48.000 AVER. PROD RATE PER MONTH          83.333

COST RANGES               DEVELOPMENT        PRODUCTION        TOTAL COST
     FROM                     192431.          2696027.          2888458.
     CENTER                   211697.          3047064.          3258761.
     TO                       237871.          3459016.          3696888.
```

Figure A-2. **TYPICAL MODEL OUTPUT DATA SHEET**

APPENDIX B

SYSTEM PARTS LISTS AND
COST-DEVELOPMENT DATA SHEETS

This appendix contains the work-sheets used to develop costs of modules and systems employed in the various options. These costs were the basis for the calculations presented in Chapter Five of the report. The sheets are grouped by system configuration in the five sections of this appendix.

	Page
B-1 - GPS Receiver, High-Performance Aircraft	B-3
B-2 - GPS Control and Display, High-Performance Aircraft	B-25
B-3 - GPS Preamplifier, High-Performance Aircraft	B-33
B-4 - GPS Receiver, Low-Performance Aircraft	B-35
B-5 - GPS Control and Display, Low-Performance Aircraft . . .	B-51

APPENDIX B-1

GPS RECEIVER, HIGH-PERFORMANCE AIRCRAFT

SYSTEM GPS Receiver

SUB-ASSEMBLY CDU I/O

SHEET 1 OF 20

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
4040	1	2.43	2.43		10			
4069	2	.64	1.28		16			
54LS03	1	.65	.65		8			
54LS27	2	.65	1.30		16			
54LS74	1	1.32	1.32		8			
54LS240	2	3.41	6.82		24			
55116	1	4.47	4.47		10			
6402	1	20.60	20.60		20			
Resistors	7	.03	.21		35			
Capacitor-T	5	.18	.90		25			
Capacitor-Disc	1	.06	.06		5			
P.C. Board	1	5.00	5.00		25			
Board Process				333	485			
TOTALS			45.04	333x2= 666	687 x 2 = 1374			

SYSTEM GPS Receiver

SUB-ASSEMBLY CPU

SHEET 2 OF 20

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
LSI-11 CUP	Set	83.00	83.00		20			
4015	3	10.15	30.45		30			
4515	1	6.30	6.30		10			
4528	1	2.22	2.22		10			
54C02	4	.39	1.56		32			
54C14	1	2.98	2.98		8			
70C97	1	.93	.93		8			
7870	1	6.25	6.25		10			
ULN2001A	2	1.12	2.24		12			
2N3467	1	.46	.46		6			
1N4454	13	.13	1.69		65			
Resistor Network	6	.95	5.70		60			
Resistors	10	.03	.30		50			
Capacitor	1	.18	.18		5			
Capacitor-Disc	2	.06	.12		10			
P.C. Board	1	5.00	5.00		25			
Board Process				333	485			
TOTALS			149.38	333 x 2 = 666	846 x 2 = 1692			

SYSTEM GPS Receiver

SUB-ASSEMBLY Memory Control

SHEET 3 OF 20

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
2102	16	3.95	63.20		320			
2114	16	8.50	136.00		320			
54LS00	3	.64	1.92		24			
54LS02	1	.64	.64		8			
54LS04	3	.71	2.13		24			
54LS05	1	.71	.71		8			
54LS08	1	.64	.64		8			
54LS10	1	.64	.64		8			
54LS11	1	.64	.64		8			
54LS30	2	.64	1.28		16			
54LS32	4	.64	2.56		32			
54LS74	1	1.28	1.28		10			
54LS75	1	4.68	4.68		10			
54LS109	1	1.28	1.28		10			
54LS138	1	2.27	2.27		10			
54LS240	4	3.41	13.64		80			
54LS373	2	8.00	16.00		40			
54C902	2	.93	1.86		20			
1N4454	3	.13	.39		15			
MA78MG	1	5.00	5.00		8			
Resistors	4	.03	.12		20			
Capacitors	22	.06	1.32		110			
TOTALS								

SYSTEM GPS Receiver SHEET 4 OF 20

SUB-ASSEMBLY Memory Control (Cont'd)

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
P.C. Board	1	5.00	5.00		25			
Board Process				333	485			
TOTALS			264.20	333 x 2 = 666	1619 x 2 = 3238			

SYSTEM GPS Receiver

SUB-ASSEMBLY Memory

SHEET 5 OF 20

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
54LS242	4	3.34	13.36		40			
54LS244	2	3.41	6.82		40			
54LS138	2	2.27	4.54		20			
93453	12	24.45	293.40		240			
1N645	3	.13	.39		15			
Resistors	2	.03	.06		10			
Capacitors	17	.06	1.02		85			
P.C. Board	1	5.00	5.00		25			
Board Process				333	485			
TOTALS			324.54	333 x 2 = 666	960 x 2 = 1920			

SYSTEM GPS Receiver

SUB-ASSEMBLY Receiver I/O

SHEET 6 OF 20

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
25LS148	1	5.03	5.03		10			
4001	2	.64	1.28		16			
4011	2	.64	1.28		16			
4013	5	1.28	6.40		40			
4035	2	2.68	5.36		20			
4040	1	2.43	2.43		10			
4068	1	.64	.64		8			
4069	2	.64	1.28		16			
4093	1	3.44	3.44		8			
54LS00	1	.64	.64		8			
54LS04	3	.71	2.13		24			
54LS05	1	.71	.71		8			
54LS08	2	.64	1.28		16			
54LS11	1	.64	.64		8			
54LS12	1	.80	.80		8			
54LS20	1	.64	.64		8			
54LS27	1	.64	.64		8			
54LS74	3	4.20	12.60		24			
54LS138	4	2.27	9.08		40			
54LS164	1	2.74	2.74		8			
54LS175	3	2.54	7.62		30			
54LS240	5	3.41	17.05		70			
TOTALS								

SYSTEM GPS Receiver

SUB-ASSEMBLY Receiver I/O (Con'd)

SHEET 7 OF 20

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
54LS244	1	3.41	3.41		10			
54LS273	1	2.46	2.46		16			
70C97	3	4.53	13.59		24			
1N4454	1	.13	.13		5			
Res. Network	3	.95	2.85		24			
Resistor 5%	10	.05	.50		50			
Resistors	3	.03	.09		15			
Capacitors	9	.06	.54		45			
P.C. Board	1	5.00	5.00		25			
Board Process				333	485			
TOTALS			112.28	333 x 2 = 666	1095 x 2 = 2190			

SYSTEM GPS Receiver

SUB-ASSEMBLY C/A Coder

SHEET 8 OF 20

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
CA3026	1	.60	.60		10			
4025	1	.64	.64		8			
4050	1	1.28	1.28		10			
4075	2	.64	1.28		16			
4094	3	2.15	6.45		30			
54C00	1	2.72	2.72		8			
54C02	2	2.72	5.44		16			
54C04	2	2.72	5.44		16			
54C08	2	2.72	5.44		16			
54C74	4	4.53	18.12		32			
54C107	4	5.38	21.52		32			
54C162	2	7.58	15.16		20			
54C163	5	7.58	37.90		50			
54C174	2	9.86	19.72		20			
54C221	1	6.44	6.44		20			
70C97	5	4.53	22.65		50			
54S00	1	3.77	3.77		8			
54LS10	2	.64	1.28		16			
54S112	1	7.08	7.08		10			
9LS00	3	.64	1.92		24			
9LS02	2	.64	1.28		16			
9LS04	3	.71	2.13		24			
TOTALS								

SYSTEM GPS Receiver

SUB-ASSEMBLY C/A Coder (Cont'd)

SHEET 9 OF 20

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
9LS11	1	.64	.64		8			
9LS27	1	.64	.64		8			
9LS32	1	.64	.64		8			
9LS51	1	.64	.64		8			
9LS74	3	1.28	3.84		24			
9LS112	5	1.28	6.40		50			
96L02	1	1.56	1.56		8			
25LS162	1	2.49	2.49		10			
25LS163	1	2.49	2.49		10			
25LS275	1	2.54	2.54		10			
25LS195	1	2.54	2.54		10			
2N3251A	2	.53	1.06		10			
5082-2800	2	.22	.44		10			
Res. Network	2	.35	.70		16			
Resistors	23	.03	.69		115			
Capacitors	25	.06	1.50		125			
Inductors	3	.06	.18		18			
Transformer	1	2.25	2.25		15			
RF Connector	1	.95	.95		25			
P.C. Board	1	5.00	5.00		25			
Board Process				333	485			
TOTALS			225.45	333 x 2 = 666	1450 x 2 = 2900			

SYSTEM GPS Receiver

SUB-ASSEMBLY UTC

SHEET 10 OF 20

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
4013	4	1.28	5.12		32			
4070	1	.64	.64		8			
4075	2	.64	1.28		16			
4076	13	3.50	45.50		130			
40097	2	1.41	2.82		20			
40162	2	2.56	5.12		20			
40163	3	2.56	7.68		30			
40174	4	2.22	8.88		40			
9LS00	2	.64	1.28		16			
9LS08	1	1.73	1.73		8			
9LS51	1	.64	.64		8			
9LS74	5	1.28	6.40		40			
9LS112	5	1.28	6.40		50			
9LS04	4	.71	2.84		32			
25LS163	3	2.49	7.47		30			
25LS194	1	3.32	3.32		10			
54S10	1	.64	.64		8			
25LS162	1	2.49	2.49		10			
54S112	1	7.08	7.08		10			
54C02	1	2.72	2.72		8			
54C20	1	2.72	2.72		8			
54C04	1	2.72	2.72		8			
TOTALS								

SYSTEM GSP Receiver

SUB-ASSEMBLY UTC (Cont'd)

SHEET 11 OF 20

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
54C107	2	5.38	10.76		16			
Res. Network	1	.35	.35		8			
Resistors	22	.03	.66		110			
Capacitors	31	.06	1.86		155			
Inductor	4	.06	.24		24			
Inductor-Tun	1	.18	.18		10			
RF Conn.	1	.95	.95		25			
P.C. Board	1	5.00	5.00		25			
Board Process				333	485			
TOTALS			145.49	333 x 2 = 666	1400 x 2 = 2800			

SYSTEM GPS Receiver

SUB-ASSEMBLY Baseband

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
MC1596	2	5.15	10.30		20			
LH0070	2	6.50	13.00		20			
LM193	4	5.00	20.00		40			
8023	7	8.53	59.71		70			
LM4250	4	6.00	24.00		24			
LF155	2	8.50	17.00		16			
LM108	2	7.32	14.64		16			
LM113	2	7.50	15.00		16			
LH24250	1	16.95	16.95		20			
CD4001	1	.64	.64		8			
CD4011	1	.64	.64		8			
CD4096	1	.64	.64		8			
CD40174	2	2.22	4.44		20			
54C221	2	5.72	11.44		20			
CD4075	1	.64	.64		8			
AD537	1	18.00	18.00		10			
AD532	2	32.50	65.00		20			
2N3251A	5	.53	2.65		30			
2N3799	2	2.35	4.70		12			
2N3811	2	7.25	14.50		12			
1N3595	14	.96	13.44		70			
1N4099	6	2.90	17.40		30			
TOTALS								

SYSTEM GPS Receiver

SUB-ASSEMBLY Baseband (Cont'd)

SHEET 13 OF 20

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
1N4100	2	2.90	5.80		10			
1N4101	4	2.90	11.60		20			
1N4454	13	.13	1.69		65			
Res. Network	13	.35	4.55		104			
Resistors	139	.03	4.17		695			
Trim Pot	5	1.35	6.75		75			
Inductor	3	.75	2.25		45			
Capacitor-T	55	.18	9.90		275			
Capacitor-Disc	26	.06	1.56		130			
Switch D/SPST	1	1.75	1.75		25			
Switch D/DPST	1	1.95	1.95		25			
Switch T/SPST	6	2.25	13.50		150			
Switch	1	.95	.95		25			
P.C. Board	1	5.00	5.00		25			
Board Process				333	485			
TOTALS			416.15	333 x 2 = 666	2652 x 2 = 5304			

SYSTEM GPS Receiver

SUB-ASSEMBLY RF/IF

SHEET 14 OF 20

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
54LS74	1	1.28	1.28		8			
MC1590	1	3.75	3.75		8			
LM139	1	7.98	7.98		8			
1B0265	1	39.75	39.75		10			
TO-CBD-113	1	29.00	29.00		10			
R-CHD-113	1	39.00	39.00		10			
MA78MG	1	5.00	5.00		8			
HYTR2101	2	.72	1.44		12			
MRF904	4	2.75	11.00		60			
2N2857	3	1.85	5.55		18			
2N4416	1	.72	.72		6			
3N200	2	.65	1.30		12			
HA2-2700	1	4.00	4.00		6			
GC4215	7	1.25	8.75		35			
5082-2835	2	.35	.70		10			
1N831B	2	2.25	4.50		10			
1N914	2	.13	.26		10			
1N5416	1	.35	.35		5			
Pluristor	3	1.93	5.79		18			
Crystals	4	5.00	20.00		60			
Filter-Conn	1	15.00	15.00		45			
Filter	10	1.38	13.80		100			
TOTALS								

SYSTEM GPS Receiver

SUB-ASSEMBLY RF/IF (Cont'd)

SHEET 15 OF 20

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Transformer	3	7.50	22.50		45			
Inductor	28	.50	14.00		168			
Resistors	130	.03	3.90		650			
Capacitor-T	37	.18	6.66		185			
Capacitor-Disc	66	.06	3.96		330			
Cap. Variable	5	.35	1.75		75			
Connector	2	1.50	3.00		30			
Stripline	1	20.00	20.00	485	25			
Cast Enclosure	1	2.50	2.50	450	25			
Cover	1	1.50	1.50	184	20			
Misc-Hardware	Lot	5.00	5.00		150			
P.C. Board	1	5.00	5.00		25			
Board Process				333	485			
TOTALS			308.69	1452 x 2.5 = 3630	2682 x 2.5 = 6705			

SYSTEM GPS Receiver

SUB-ASSEMBLY Synthesizer

SHEET 16 OF 20

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
CA3026	6	.60	3.60		48			
CA3049	2	.90	1.80		16			
MA78MG	1	5.00	5.00		8			
Crystal Filter	5	24.13	120.65		125			
Crystal Filter	2	9.00	18.00		50			
5082-2800	2	.90	1.80		10			
2N2222A	2	.13	.26		12			
Pwr Divider	2	6.00	12.00		16			
Inductor-Var.	11	1.65	18.15		165			
Transformer-Var	20	.95	19.00		300			
Transformer	2	1.35	2.70		30			
Choke	3	.35	1.05		18			
Inductor	2	.18	.36		12			
Resistor	124	.03	3.72		620			
Capacitor-T	82	.18	9.84		410			
Capacitor-Disc	65	.06	3.90		325			
Cap W/seal	3	1.50	4.50		30			
Connector	9	1.50	13.50		135			
Cast Enclosure	1	2.50	2.50	450	25			
Cover	1	1.50	1.50	184	20			
Misc. Hardware	Lot	3.00	3.00		100			
P.C. Board	1	5.00	5.00	333	510			
TOTALS			251.83	967 x 1.5 = 1450	2985 x 1.5 = 4478			

SYSTEM GPS Receiver SHEET 17 OF 20

SUB-ASSEMBLY Power Supply

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
MA78MG	2	5.00	10.00		16			
6100-1032	1	1.71	1.71		8			
LM567	1	7.50	7.50		8			
5474	1	1.39	1.39		8			
DS0026	1	7.75	7.75		8			
NA747	1	5.45	5.45		8			
NA79MG	1	5.00	5.00		8			
LM139	3	2.00	6.00		24			
2N2907A	1	.32	.32		6			
6100-1042	2	1.43	2.86		12			
6100-1068	2	2.21	4.42		12			
2N2222A	2	.40	.80		12			
SCR	1	3.00	3.00		6			
Zener	2	1.02	2.04		10			
1N751	1	.40	.40		5			
1N823	2	2.50	5.00		10			
1N758A	1	2.20	2.20		5			
4N24	1	.75	.75		8			
1N6080	4	.74	2.96		20			
1N4454	15	.20	3.00		75			
1N6073	8	.38	3.04		40			
Diode	6	1.01	6.06		30			
TOTALS								

SYSTEM GPS Receiver

SUB-ASSEMBLY Power Supply (Cont'd)

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
1N4938	2	.10	.20		10			
Diode Assembly	3	2.50	7.50		36			
Bridge Rectifier	1	4.23	4.23		15			
Bridge Rectifier	1	1.12	1.12		15			
Varactor	1	3.59	3.59		10			
Beads	36	.05	1.80		180			
Resistors	75	.03	2.25		375			
Capacitors-T	57	.18	12.51		285			
Capacitors-Disc	5	.06	.30		25			
P.C. Board	1	5.00	5.00		25			
Board Process				333	485			
TOTALS			120.15	333 x 1.5 = 500	1800 x 1.5 = 2700			

SYSTEM GPS Receiver

SUB-ASSEMBLY Enclosure & Chassis

SHEET 19 OF 20

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Oscillator	1	1.60	1.60		35			
Chassis	1	4.50	4.50	184	44			
Enclosure	1	2.50	2.50	247	88			
Front Plate	1	1.50	1.50	74	22			
P.C. Connectors	11	1.55	17.05		275			
Rear Connector	2	40.00	80.00		50			
Wiring	Lot	7.50	7.50		2000			
Conn. Plate	2	.25	.50		50			
Conn. Brackets	22	.10	2.20	50	550			
Power Transf.	1	15.00	15.00		615			
Stand-Off	2	.75	1.50	118	8			
RF Cables	7	1.50	10.50		210			
Nameplate	1	.50	.50	60	15			
Misc. Hardware	Lot	10.00	10.00		300			
TOTALS			313.25	733	4262			

SYSTEM GPS Receiver

SUB-ASSEMBLY Assembly & Test

SHEET 20 OF 20

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
CDU I/O					25			
CPU					25			
Memory Control					25			
Memory					25			
Receiver I/O					25			
CA Coder					25			
RX Control					25			
Baseband					25			
RF/IF					25			
Synthesizer					25			
Power Supply					40			
Chassis					100			
Burn-In					1000			
Functional Test					3000			
TOTALS					4390			

APPENDIX B-2

GPS CONTROL AND DISPLAY, HIGH-PERFORMANCE AIRCRAFT

SYSTEM Control Indicator

SUB-ASSEMBLY Display

SHEET ______ OF ______

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
54C175	8	1.86	14.88		80			
4013	1	1.28	1.28		10			
55116	1	5.84	5.84		10			
6402	1	21.20	21.20		10			
Resistor Pack	4	.95	3.80		32			
Capacitors	5	.06	.30		20			
Resistor	1	.03	.03		5			
P.C. Board	1	5.00	5.00		25			
Board Process				333	485			
TOTALS			52.33	333	677 x 1.5 = 1016			

SYSTEM Control Indicator

SUB-ASSEMBLY Driver

SHEET ______ OF ______

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
54L310	1	.64	.64		8			
54LS138	2	2.27	4.54		20			
14532	2	3.13	6.26		20			
70C97	2	.93	1.86		20			
54C901	1	.93	.93		10			
54C175	1	1.86	1.86		10			
4028	2	2.05	4.10		16			
4071	1	.64	.64		8			
555	1	2.50	2.50		8			
1N4454	4	.30	1.20		20			
2N5327	5	9.25	46.25		30			
Resistor Pack	5	.95	4.75		40			
Cap T	4	.18	.72		20			
Cap D	3	.06	.18		15			
2N2907A	5	.26	1.30		30			
Resistor	1	.03	.03		5			
P.C. Board	1	5.00	5.00		25			
Board Process				333	485			
TOTALS			82.76	333	790 x 1.5 = 1185			

SYSTEM Control Indicator

SUB-ASSEMBLY Control

SHEET ______ OF ______

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
54LS00	1	.64	.64		8			
54LS10	1	.64	.64		8			
54LS109	1	1.28	1.28		10			
54LS145	1	3.11	3.11		10			
54LS123	1	1.57	1.57		10			
54LS04	1	.71	.71		8			
54LS175	1	2.54	2.54		10			
5402	1	.85	.85		8			
MC12561	1	5.91	5.91		14			
54C161	1	2.12	2.12		10			
4040	1	2.43	2.43		10			
6800	1	19.00	19.00		14			
6561	2	8.40	16.80		28			
MCM68308	3	10.10	30.30		30			
3467	1	8.00	8.00		10			
1N4454	1	.30	.30		5			
Resistor Pack	2	.95	1.90		16			
Capacitors	14	.06	.84		70			
Resistors	4	.03	.12		20			
Crystal-10mHz	1	2.50	2.50		15			
P.C. Board	1	5.00	5.00		25			
Board Process				333	485			
TOTALS			106.56	333	824 x 1.5 = 1236			

SYSTEM Control Indicator

SHEET ______ **OF** ______

SUB-ASSEMBLY Pwr Sup.

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
LAS-14U	1	12.00	12.00		25.00			
MZ5555	1	3.60	3.60		15.00			
Potentiometer	1	1.80	1.80		15.00			
Capacitor-E	1	.95	.95		15.00			
Capacitor-T	1	.18	.18		5.00			
P.C.. Board	1	5.00	5.00		25.00			
Board Process				333	485.00			
TOTALS			23.53	333	585 x 1.5 = 878			

SYSTEM Control Indicator

SUB-ASSEMBLY End & Chassis

SHEET ______ OF ______

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Front Panel	1	5.00	5.00	74	22			
Keyboard	1	4.35	4.35		25			
Sel. Switch	1	4.39	4.39		15			
LED Display	11	1.05	11.55		110			
LED Lights	5	.22	1.10		25			
Potentiometer	1	1.80	1.80		15			
Toggle Switch	1	.35	.35		15			
Chassis	1	3.50	3.50	184	44			
Cover	1	2.00	2.00	334	5			
P.C. Connectors	4	1.95	7.80		60			
MS Conn.	1	6.78	6.78		25			
LED Sockets	1	7.15	7.15		25			
LED Bezel	1	3.15	3.15		15			
Resistors	11	.03	.33		55			
Wiring	Lot	1.50	1.50		500			
TOTALS			60.75	592	956			

SYSTEM Control Indicator SHEET ______ OF ______

SUB-ASSEMBLY Assembly & Test

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Display P.C.	1				25			
Driver P.C.	1				25			
Control P.C.	1				25			
Pwr. Sup. P.C.	1				25			
End & Chassis	1				100			
Functional Test					1000			
Burn-In					1000			
TOTALS					2200			

APPENDIX B-3

GPS PREAMPLIFIER, HIGH-PERFORMANCE AIRCRAFT

SYSTEM Preamplifier

SUB-ASSEMBLY ________

SHEET ______ OF ______

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
HXTR-2101	1	12.00	12.00		6			
-6104	1	120.00	120.00		12			
-6105	1	36.00	36.00		12			
2N3486A	3	4.60	13.80		18			
Capacitors	21	.06	1.26		105			
Resistors	15	.03	.45		75			
Filter	1	2.30	2.30		25			
Capacitor-F-T1.2	4	.45	1.80		40			
Connector-RF	2	1.37	2.74		50			
Housing	1	2.50	2.50	184	44			
Cover	1	1.50	1.50	48	20			
P.C. Board	1	5.00	5.00		25			
Board Process				333	485			
Misc. Hardware	Lot	1.50	1.50		100			
Burn-In					500			
Functional Test					1000			
Isolator	1	15.00	15.00		25			
TOTALS			215.85	565	2542 x 1.5 = 3813			

APPENDIX B-4

GPS RECEIVER, LOW-PERFORMANCE AIRCRAFT

SYSTEM GPS-GA

SUB-ASSEMBLY Receiver

SHEET ______ OF ______

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
74S10	1	.49	.49		8			
74LS162	1	1.49	1.49		10			
74S112	1	1.11	1.11		10			
9LS00	2	.27	.54		16			
9LS08	1	.27	.27		8			
9LS74	5	.43	2.15		40			
9LS51	1	.27	.27		8			
9LS112	5	.43	2.15		50			
74LS194	1	2.87	2.87		10			
9LS04	4	.30	1.20		32			
74C02	1	.27	.27		8			
74C20	1	.27	.27		8			
74C04	1	.30	.30		8			
74C107	2	1.26	2.52		16			
40162	2	1.42	2.84		20			
40163	8	1.42	11.36		80			
4013	4	.76	3.04		32			
4076	13	1.88	24.44		130			
40174	4	1.28	5.12		40			
4070	1	.35	.35		8			
40097	2	.83	1.66		20			
4075	2	.32	.64		16			
TOTALS								

SYSTEM GPS-GA

SUB-ASSEMBLY Receiver

SHEET ______ OF ______

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
MC1596	2	2.65	5.30		20			
LM741	2	1.25	2.50		20			
LM747	4	.95	3.80		40			
8023	7	4.25	29.75		70			
8021	4	1.20	4.80		32			
LF155	2	3.50	7.00		16			
LM108	2	3.99	7.98		16			
LM329	2	1.00	2.00		16			
LM4250	2	1.20	2.40		16			
4011	1	.35	.35		8			
4001	1	.35	.35		8			
4069	1	.35	.35		8			
40174	2	1.28	2.56		20			
74C221	2	1.45	2.90		20			
4075	1	.32	.32		8			
AD537 mod	1	3.00	3.00		10			
AD532 mod	2	3.50	7.00		20			
2N3811 eq	4	.35	1.40		24			
2N3799	2	2.35	4.70		12			
1N5235	6	.40	2.40		30			
1N5237	4	.40	1.60		20			
1N3595	14	.96	13.44		70			
TOTALS								

SYSTEM GPS-GA

SUB-ASSEMBLY Receiver

SHEET ______ OF ______

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
1N958	2	.40	.80		10			
2N3251	5	.30	1.50		30			
1N4454	13	.13	1.69		65			
Switch D/SPST	1	.44	.44		25			
Switch D/DPST	1	.88	.88		25			
Switch T/SPST	6	.90	5.40		150			
Switch	1	.30	.30		25			
Trim Pot	5	.35	1.75		75			
Connector-RF	1	.85	.85		25			
Inductors	8	.06	.48		48			
Capacitors	112	.06	6.72		560			
Resistors	161	.03	4.83		805			
PC Board	1	5.00	5.00		25			
Board Process	-	--	--	333	485			
TOTALS			201.89	333	3435 x 1.5 = 5153			

SYSTEM GPS-GA   SHEET ______ OF ______

SUB-ASSEMBLY Processor #1

ITEM NAME OR CATEGORY 1024 x 4	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
MM2114N	16	4.15	66.40		320			
MM2102	16	2.15	34.40		320			
74LS00	3	.27	.81		24			
74LS02	1	.27	.27		8			
74LS04	3	.30	.90		24			
74LS05	1	.30	.30		8			
74LS11	1	.27	.27		8			
74LS30	2	.27	.54		16			
74LS32	4	.28	1.12		32			
74LS10	1	.27	.27		8			
74LS74	1	.43	.43		10			
74LS109	1	.43	.43		10			
74LS240	4	1.73	6.92		80			
74LS75	1	.39	.39		10			
74S373	2	4.30	8.60		40			
74LS08	1	.27	.27		8			
74LS138	3	1.28	3.84		30			
74C902	2	.71	1.42		20			
74LS244	2	1.73	3.46		40			
74LS242	4	1.67	6.68		40			
MCM6560	12	6.80	81.60		240			
1N645	3	.13	.39		15			
TOTALS								

SYSTEM GPS-GA

SUB-ASSEMBLY Processor #1

SHEET ______ OF ______

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
1N4454	3	.13	.39		15			
UA78MGHC	1	1.46	1.46		8			
Capacitors	39	.06	2.34		195			
Resistors	6	.03	.18		30			
P.C. Board	1	5.00	5.00		25			
Board Process	-	--	--	333	485			
TOTALS			229.08	333	2069 x 1.5 = 3104			

SYSTEM GA-GPS SHEET ____ OF ____

SUB-ASSEMBLY Processor #2

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
(MM5303) 6402	1	3.25	3.25		20			
74LS240	2	1.73	3.46		24			
74LS27	2	.27	.54		16			
74LS03	1	.27	.27		8			
74LS74	1	.43	.43		8			
55116	1	4.47	4.47		10			
4040	1	1.35	1.35		10			
4069	2	.35	.70		16			
7870	1	1.75	1.75		10			
4015	3	1.28	3.84		30			
4528	1	1.28	1.28		10			
4515	1	3.50	3.50		10			
74C14	1	.78	.78		8			
70C97	1	.93	.93		8			
74C02	4	.35	1.40		32			
CPU (IPC-16A)	1	26.00	26.00		20			
2N2001A	2	1.12	2.24		12			
2N3467	1	.46	.46		6			
1N4454	13	.13	1.69		65			
Resistors	24	.03	.72		120			
Capacitors	9	.06	.54		45			
P.C. Board	1	5.00	5.00	333	485			
TOTALS			64.60	333	973 x 2 = 1946			

SYSTEM GPS-GA SHEET ______ OF ______

SUB-ASSEMBLY Processor #3

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
70C97	3	.93	2.79		24			
74LS240	5	1.73	8.65		70			
74LS244	1	1.73	1.73		10			
4069	2	.35	.70		16			
4035	2	1.49	2.98		20			
4040	1	1.35	1.35		10			
4013	5	.76	3.80		40			
4093	1	1.46	1.46		8			
74LS27	1	.27	.27		8			
4011	2	.35	.70		16			
4068	1	.35	.35		8			
74LS04	5	.30	1.50		40			
74LS08	4	.27	1.08		32			
74LS05	1	.30	.30		8			
74LS138	4	1.28	5.12		40			
74LS273	1	2.04	2.04		16			
74LS74	7	.43	3.01		56			
74LS175	3	1.28	3.84		30			
74LS12	1	.29	.29		8			
74LS11	1	.27	.27		8			
4001	2	.35	.70		16			
25LS148	1	1.37	1.37		10			
TOTALS								

SYSTEM GPS-GA SHEET ______ OF ______

SUB-ASSEMBLY Processor #3 (con'd)

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
74LS20	1	.27	.27		8			
74LS00	3	.27	.81		24			
74LS164	1	1.34	1.34		8			
3026	1	.60	.60		10			
4025	1	.32	.32		8			
4050	1	.76	.76		10			
4075	2	.32	.64		16			
4094	3	1.60	4.80		30			
74C02	2	.26	.52		16			
74LS107	4	.44	1.76		32			
74LS162	2	1.49	2.98		20			
74LS163	5	1.49	7.45		50			
74LS174	2	1.28	2.56		20			
74LS221	1	1.20	1.20		20			
70C97	5	.93	4.65		50			
74LS10	2	.27	.54		16			
74LS112	1	.43	.43		10			
9LS00	3	.27	.81		24			
9LS02	2	.27	.54		16			
96L02	1	.79	.79		8			
9LS04	3	.30	.90		24			
9LS11	1	.27	.27		8			
TOTALS								

SYSTEM GPS-GA　　　　　　　　　　　　　　　　SHEET ______ OF ______

SUB-ASSEMBLY Processor #3 (cont'd)

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
9LS27	1	.27	.27		8			
9LS32	1	.28	.28		8			
9LS51	1	.27	.27		8			
9LS74	3	.43	1.29		24			
9LS112	5	.43	2.15		50			
25LS162	1	1.49	1.49		10			
25LS175	1	1.28	1.28		10			
1N4454	1	.13	.13		5			
5082-2800	2	.22	.44		10			
Inductors	3	.06	.18		18			
Capacitors	34	.06	2.04		170			
Resistors	38	.03	1.14		190			
2N3251A	2	.53	1.06		12			
RF Conn.	1	.35	.35		25			
P.C. Board	1	5.00	5.00		25			
Board Process		--	--	333	485			
TOTALS			96.61	333	1980 x 1.5 = 2970			

SYSTEM GPS-GA

SUB-ASSEMBLY RF Module

SHEET ______ OF ______

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Filter	1	4.50	4.50		25			
SRF215	2	.80	1.60		12			
MMT74	3	1.77	5.31		18			
SRF462	3	.95	2.85		18			
Transformers	3	.35	1.05		45			
Coils	6	.06	.36		18			
Trans. (L.O.Input)	3	.78	2.34		45			
2N5138	2	.23	.46		12			
ULN2136	1	1.30	1.30		8			
Hot Carrier Diodes	4	.57	2.28		20			
Capacitors	18	.06	1.08		90			
Resistors	28	.03	.84		140			
2N5172	2	.13	.26		12			
Trans. Mixer	1	1.16	1.16		25			
P.C. Board	1	5.00	5.00		25			
Board Process	--	--	--	333	485			
Chassis	1	.75	.75	92	24			
Cover	1	.50	.50	41	22			
Connector	2	.35	.70		50			
TOTALS			32.34	466	1094 x 1.5 = 1641			

SYSTEM GPS-GA

SUB-ASSEMBLY Synthesizer

SHEET ______ OF ______

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Ind - VAR	11	.46	5.06		330			
Trans - VAR	20	.37	7.40		800			
Trans - Fixed	2	.35	.70		80			
F.Hers, XTAL	7	4.94	34.58		105			
5082 - 2800	2	.13	.26		10			
Choke	3	.51	1.53		75			
Inductor	1	.52	.52		5			
2N2222A	2	.35	.70		12			
CA3026	6	1.46	8.76		48			
CA3049	2	1.05	2.10		12			
78MG	1	1.46	1.46		8			
Capacitors	150	.06	9.00		750			
Resistors	124	.03	3.72		620			
Connector	12	.35	4.20		300			
P.C. Board	1	5.00	5.00		25			
Board Process	--	--		333	485			
Chassis	1	.75	.75	92	24			
Cover	1	.50	.50	41	22			
Misc. Hardware	Lot	1.50	1.50		100			
TOTALS			87.74	466	3326			

SYSTEM GPS-GA

SUB-ASSEMBLY Power Supply

SHEET ______ OF ______

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
2N4899	1	1.10	1.10		6			
2N5086	1	.21	.21		6			
MC1563G	1	5.25	5.25		8			
2N4911	1	.95	.95		6			
2N5089	1	.27	.27		6			
MC1569G	1	4.50	4.50		8			
2N3055	1	.90	.90		6			
1N457A	1	.19	.19		5			
1N4733A	1	.60	.60		5			
1N4003	1	.13	.13		5			
Potentiometers	2	.35	.70		50			
Cap. T	4	.18	.72		20			
Cap. C	3	.06	.18		15			
Resistors	7	.03	.21		35			
PC Board	1	3.00	3.00		25			
Board Process	-	--	--	333	485			
TOTALS			18.19	333	691			

SYSTEM GPS-GA

SUB-ASSEMBLY Enclosure & Chassis

SHEET ______ OF ______

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Chassis	1	2.50	2.50	184	44			
Cover-L-R	2	.50	1.00	50	22			
Panel F-R	2	1.50	3.00	148	44			
P.C. Board Assbly	1	1.25	1.25	150	75			
Cover Top	1	.50	.50	25	11			
Cover, Bottom	1	.50	.50	25	11			
Connector-RF	1	.95	.95		15			
Connector,Cable	1	.95	.95		25			
Connector,PCBd	7	.35	2.45		175			
Support Bracket	2	.50	1.00	92	24			
Retaining Strap	2	.75	1.50	28	10			
Misc. Hardware	Lot	3.50	3.50		250			
Wiring	Lot	5.00	5.00		1000			
TOTALS			24.10	702	1706			

SYSTEM GPS-GA

SUB-ASSEMBLY Assembly & Test

SHEET ______ OF ______

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Receiver	1				50			
Processor #1	1				25			
Processor #2	1				25			
Processor #3	1				25			
RF/IF	1				25			
Synthesizer	1				25			
Power Supply	1				25			
Enclosure & Chassis	1				100			
P.S. Alignment					100			
Rx Alignment					200			
Burn-In					1000			
Functional Test					1000			
Oscillator	1				25			
TOTALS					2625			

APPENDIX B-5

GPS CONTROL AND DISPLAY, LOW-PERFORMANCE AIRCRAFT

SYSTEM GPS-GA Control

SUB-ASSEMBLY Display Board

SHEET ______ OF ______

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
74175	8	.79	6.32		80			
4013	1	.76	.76		10			
75116	1	1.87	1.87		10			
5303	1	3.25	3.25		10			
Resistor Pack	4	.45	1.80		32			
Capacitors	5	.06	.30		20			
Resistor	1	.03	.03		5			
PC Board	1	5.00	5.00		25			
Board Process	-	-	-	333	485			
TOTALS			19.33	333	677x1.5 = 1016			

SYSTEM GPS-GA Control

SUB-ASSEMBLY Driver

SHEET ______ OF ______

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
74LS10	1	.27	.27		8			
74LS138	2	1.28	2.56		20			
14532	2	1.74	3.48		20			
70C97	2	.93	1.86		20			
74C901	1	.71	.71		10			
4028.	2	1.17	1.17		10			
4071	1	1.14	2.28		16			
555	1	.35	.35		8			
IN4454	4	.30	1.20		20			
2N5324	5	2.44	12.20		30			
Resistor Pack	5	.45	2.25		40			
Cap T	4	.18	.72		20			
Cap D	3	.06	.18		15			
2N2907A	5	.26	1.30		30			
Resistor	1	.03	.03		5			
PC Board	1	5.00	5.00		25			
Board Process	-	-		333	485			
TOTALS			35.83	333	790x1.5 = 1185			

SYSTEM GPS-GA Control

SUB-ASSEMBLY Control

SHEET ______ OF ______

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
74LS00	1	.27	.27		8			
74LS10	1	.27	.27		8			
74LS109	1	.43	.43		10			
74LS145	1	1.01	1.01		10			
74LS123	1	.81	.81		10			
74LS04	1	.30	.30		8			
74LS175	1	1.28	1.28		10			
7402	1	.35	.35		8			
MC12061	1	2.87	2.87		14			
74C161	1	1.18	1.18		10			
4040	1	1.35	1.35		10			
8080A	1	8.70	8.70		14			
5230	2	5.88	11.76		28			
5242	3	5.88	17.64		30			
3467	1	1.50	1.50		10			
1N4454	1	.30	.30		5			
Resistor Pack	2	.45	.90		16			
Capacitors	14	.06	.84		70			
Resistors	4	.03	.12		20			
Crystal-10mHz	1	1.50	1.50		15			
PC Board	1	5.00	5.00		25			
Board Process	-	-	-	333	485			
TOTALS			58.33	333	824x1.5 = 1236			

SYSTEM GPS-GA Control

SUB-ASSEMBLY Power Supply

SHEET ______ OF ______

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Volt Regulator	1	4.50	4.50		25			
MZ5555	1	3.60	3.60		15			
Potentiometer	1	.35	.35		15			
Capacitor - E	1	.30	.30		15			
Capacitor - T	1	.18	.18		5			
PC Board	1	2.00	2.00		25			
Board Process	-	-	-	333	485			
TOTALS			10.93	333	585			

SYSTEM GPS-GA Control

SUB-ASSEMBLY Enclosure & Chassis

SHEET ______ OF ______

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Front Panel	1	1.00	1.00	74	22			
Keyboard	1	2.75	2.75		25			
Sel Switch	1	1.35	1.35		15			
Led Display	11	1.05	11.55		110			
Led Lights	5	.22	1.10		25			
Potentiometer	1	.35	.35		15			
Toggle Switch	1	.28	.28		15			
Chassis	1	1.25	1.25	184	44			
Cover	1	.50	.50	334	5			
PC Connector	4	.35	1.40		60			
Cable Connector	1	.95	.95		25			
Led Sockets	1	1.10	1.10		25			
Led Bezel	1	.55	.55		15			
Resistors	11	.03	.33		55			
Wiring	Lot	1.50	1.50		500			
Misc. Hardware	Lot	1.00	1.00		125			
TOTALS			26.96	592	1081			

AD-A080 945 ARINC RESEARCH CORP ANNAPOLIS MD F/G 17/7
AVIONICS COST DEVELOPMENT FOR CIVIL APPLICATION OF GLOBAL POSIT--ETC(U)
APR 79 S H KOWALSKI DOT-FA76WA-3788
UNCLASSIFIED 1326-01-7-1873 FAA-EM-79-1 NL

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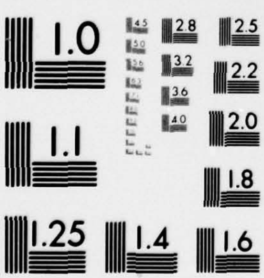

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

SHEET ____ OF ____

SYSTEM ____
SUB-ASSEMBLY ____

ITEM NAME OR	QTY	UNIT	TOTAL	LABOR HOURS PER 1000 UNITS

SYSTEM ______________ SHEET _______ OF _______

SUB-ASSEMBLY __________

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Display Board	1				25			
Driver Board	1				25			
Control Board	1				25			
Power Supply	1				50			
Chassis	1				50			
Front Panel	1				100			
Burn-In	-				1000			
Functional Test	-				1000			
TOTALS					2275			